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Refractory Uses of Bauxite.

We heartily commend to the attention of our readers a short article by Mr. A. J. Aubrey, published in this issue, on the refractory uses of bauxite, especially in open-hearth steel furnaces, in rotary Portland cement kilns and in lead refining furnaces. The problem of providing an efficient furnace lining became a burning question with the advent of extremely high temperatures in the electric furnace. The results obtained in this field are now bound to react on the practice of metallurgical furnace work with comparatively lower temperatures. It is not accidental that, in this development now going on, this journal has been the leading journalistic exponent. It is true that metallurgists have long recognized the importance of the problems involved; among others, the Thomas basic Bessemer converter stands a monument of the splendid work of the old metallurgy in this field. But it is equally true that with very few exceptions refractories have not been made up in the past with any regard as to the conditions which they will meet in the special furnace in which they are to be used, and if attention has been given to this matter, recognized authorities agree that it has been "simply guess work or sort of a hit or miss business." That this situation is now changing, Mr. Aubrey's article bears witness. More than once we have expressed our opinion on the necessity of research laboratories for our large manufacturers, and it is with great pleasure, therefore, that we say that Mr. Aubrey's article deals with the first important achievement of the new research laboratory of the Laclede Fire-Brick Mfg. Co. There is an immense work still to be done and there is room for all, but much will depend on the coöperation of manufacturer and user, of the refractory maker and the metallurgical engineer. Even those metallurgical managers who still consider research laboratories to be a fad of modern times, will become interested if they learn that by properly paying attention to the matter they may prolong the life of their furnace linings six or eight times. Mr. Aubrey's article marks undoubtedly an excellent beginning.

The Role of Current Density in Electrolytic and in Electric Furnace Processes.

In published accounts of many electrochemical processes, the importance of using a certain current density is emphasized; the amperes per square centimeter must be maintained between certain distinct limits in order to obtain the desired effect or to get maximum efficiency. On the other hand, if we compare the practice of different plants, using in principle the same process and each adhering to a certain current density considered the most profitable one under the circumstances, we find that the figures for the best current density may differ very greatly. Thus in our electrolytic copper refineries, current densities ranging between, say, 1¼ to 4 amps. per square decimeter, or 10 to 40 amps. per square foot, are used in dif-

ferent plants in this country. The reason for this somewhat surprising discrepancy is well known. Any industrial plant is a unit, and its most efficient operation depends on a great many different but interconnected factors. The current density is only one such item in an electrochemical plant, and is recognized by copper refiners to be closely interconnected—from an industrial point of view—for instance, with the cost of power, the amount of wages and the composition of the anodes. Yet in this labyrinth of industrial considerations we need an Ariadne line of thread. It is a narrow point of view if one looks on a subject only from one side, yet a search-light, which concentrates the rays to even one single point, may, nevertheless, give useful information, as long as the observer remains unbiased and does not imagine that he sees the whole thing. Though restricted, therefore, in its scope, a brief and necessarily incomplete discussion of the rôle of current density from the single view point of electrochemistry may nevertheless be useful. To be as broad as possible within our restricted limits of discussion, the consideration shall be based on the energy principle. But we may first mention a single relation which follows directly from Ohm's law and is sometimes useful in calculations. This relation states that the current density in amperes per square centimeter of cross-section equals the voltage-drop per centimeter of line of current, multiplied by the electric conductivity. This rule is valid for any cylinder, the walls of which are formed by lines of current as long as the current density is the same for all cross-sections. The rule is, of course, always correct if expressed in the terms of the differential calculus.

* * *

Let us first consider the most elementary case of an electric furnace process in which the function of the electric current is simply to heat the charge to a certain temperature and to maintain it at that temperature for a certain time. An example is the production of artificial emery by fusing calcined bauxite. When the charge is heated, a stationary condition will be reached, and if the ultimate process is simply fusion the stationary condition will correspond to the fusion temperature. In this stationary condition the amount of electrical energy will be exactly equal to the heat absorbed by the fusion plus the heat given off from the furnace to the outside by radiation and conduction. This loss of heat depends essentially on the surface design of the furnace and the heat-insulating qualities of its walls, but for a given temperature and a given furnace the watts lost per square centimeter of surface will have a certain value. The total loss of heat to the outside must be made up by the electrical energy. Thus, with a given charge it is the watts per cubic centimeter which are the important thing to look after. This will also be the case if the process does not consist in simply heating the charge with or without fusion, but is accompanied by a chemical reaction, as is the case in the conversion of anthracite coal into graphite and in the production of carborundum and calcium carbide; electrolytic effects, however, must be excluded for the present. In all these cases the electrical energy supply must equal the energy needed for the chemical and physical reactions taking place at that temperature, plus the loss of heat by radiation and conduction; if the chemical reaction is exothermic its energy is, of course, to be taken as negative. This brings up the question: If in electric furnace processes the watts per cubic centimeter are the fundamental item, what is the relation of this item to the current density? From the rule given at the end of the preceding paragraph it follows at once that the watts per cubic centimeter equal the square of the current density, multiplied by electric resistivity. This result also follows at once from the well-known formula of the Joulean heat. It means that the current density determines directly the watts per cubic centimeter, but it also emphasizes another point which, although almost elementary, is often overlooked. It is by no means always true that the resistivity is constant. With a granular charge the resistivity may, for instance, be varied within considerable limits by compressing the charge more or less tightly, and in one and the same furnace the pressure will undoubtedly vary to some extent from point to point. Moreover, the resistivity may change enormously with the temperature, and the temperature is not the same at all points throughout the furnace. For instance, the problem may be to so design a furnace as to have a gradually higher and higher temperature while approaching the tap-hole, with the highest temperature just at that point. This can, of course, be done by properly adjusting the cross-section of the furnace chamber. But the design should not be based on the amperes per square centimeter but on the watts per cubic centimeter. This would, indeed, appear to be the safest proceeding in making the calculation in all such cases.

* * *

Let us now consider the case of an electrolytic process. The energy which is supplied to an electrolytic cell will be partly changed into chemical energy, represented by the oxidation and reduction processes at the anode and cathode respectively, and partly into heat. In order to simplify the discussion, we will first get rid of the heat—which is easier on paper than sometimes in practice. We have the Joulean heat, which is covered by the discussion in the preceding paragraph, and we have also another heating effect which is thermo-electric. Even if we use a cell so large in cross-section and with the electrodes so near together that the Joulean heat would be negligible, the current will tend either to raise or decrease the temperature of the cell, and this temperature effect may be different at the two electrodes. If this latter heat effect is zero, in a special case, then, aside from the Joulean heat, the total electrical energy consumed will equal the chemical energy produced, which is Thomson's rule. If this heat effect is not zero, Helmholtz's formula is to be substituted for Thomson's rule. Now let us consider the electrical energy. This is given in watt-hours, and represents the "free energy" of the electrochemical reaction. The watt-hours are the product of ampere-hours and volts, and the ampere-hours determine directly the number of gramequivalents oxidized and reduced at the electrodes, according to Faraday's law. Thus in electroplating, every 96,540 coulombs or ampere-seconds will deposit 1 gram-atom of the metal on the cathode from a univalent salt solution. Now, if an electrolytic process goes on, the reaction, in order to proceed, requires a certain free energy; in order to get so and so many grams of a certain product, a distinct number of watt-seconds, or volt-ampere-seconds, is required. But this same weight of product also requires a distinct number of ampere-seconds according to Faraday's law. Hence, it

will be seen that the volts are also fixed. When we have an electrolyte which can give a number of different reactions—for instance, a mixture of metallic salt solutions from which the different metals may be deposited on the cathode—each reaction requires a certain number of watt-seconds, say x watt-seconds, to produce 1 gramatom of the product, but each gramatom of the product requires 96,540 n ampere-seconds where n is the change of valency during the reaction. If we have to do with metallic deposition, or with evolution of gas, n is the equal to the valency in the solution. Hence, to get a certain product the voltage must have a distinct value $0.00001036\ x \div n$, and for our metallic salt mixture we have a voltage series of such a kind that if we gradually raise the e. m. f. at the terminals, we can deposit successively one metal after the other. Each metal has a critical voltage in this mixture; with any e. m. f. below this critical voltage the metal cannot be deposited. If we have a mixture of univalent metallic salt solutions, then the decomposition of 1 gram-equivalent of each salt solution—or the deposition of 1 gram-equivalent of each metal on the cathode—will require a certain number of watt-seconds, say, successively, $x_1\ x_2\ x_3$ . . watt-seconds; *i. e.*, to deposit one metal after the other in this series, we must supply successively more and more energy; if we multiply every figure in the above watt-second series with 0.00001036, we get for univalent ions directly the voltage series; *i. e.*, to deposit one metal after the other in this series we must successively raise the voltage. With a change of valency not equal to unity, the figure 0.00001036 is simply to be divided by the valency change. In any case by a simple multiplication with a conversion factor we can "change" the free energy of the reaction—whether given in calories or watt-seconds or any other energy unit—directly into volts; and each of these conversion factors depends only on the valency change, and is otherwise entirely independent of the chemical nature of the reaction.

* * *

This is after all the quintessence of the principles governing electrolytic action. But, since this whole note is written to discuss the rôle of current density, the question suggests itself, where does the current density come in? Within the electrolyte itself its effects will be evident when looked upon from the point of view of the ionic theory. The transport of electricity through the solution occurs by the migration of ions, and the velocity of migration is—at least for dilute solutions—equal to the ionic mobility (which is a characteristic constant of each kind of ion) multiplied by the voltage drop per unit length of line of current. Now this latter quantity is, according to the rule given above at the end of the first paragraph, directly proportional to the current density. However, the chief interest in electrolytic action lies in the reactions at the electrodes, and, as we saw before, these depend essentially on the voltage. We may go further and consider the anodic and the cathodic reactions separately. Then we can say that the anodic potential drop and the cathodic potential drop determine what can and will happen at the anode and cathode respectively. If we gradually raise the voltage new reactions set in, but under the conditions how such experiments are generally carried out, the current density increases together with the voltage. Instead of a critical voltage series we could, therefore, give a critical current-density series. But the voltage series is independent of the arrangement of the experiments, while the current density depends materially on the latter. However, in all that precedes, we have simply assumed that we have a given electrolytic system, and all above considerations are strictly correct, as long as this system remains unchanged. But for all practical applications it is of the greatest importance to take the fact into account that the current itself tends to continually change the system by introducing new products at the electrodes into the system; and it is evident that here the current density is of decisive importance. The greater the current the larger is the amount of new products formed at the electrodes; further, the smaller the electrode surface the less is the quantity of electrolyte which is in contact with the electrodes, and the greater is the liability of the nearly-formed products to displace the original electrolyte. This explains, for instance, why in copper refining the best current density depends on the composition of the anode. The conditions can be clearly seen in storage battery operation. The capacity of a given lead accumulator is the smaller the shorter the time of discharge or, what is the same, the higher the rate of discharge. This is distinctly the effect of current density. The higher the current density the greater the dilution of the electrolyte in the pores of the accumulator plates and the lower the voltage, and, therefore, the efficiency. As Mr. D. H. Browne once wrote in our columns: "Close experiment will almost always reveal the proper conditions under which certain work can be done, but the continuance of these conditions is attainable only by continual vigilance, which is as much the price of liberty as it is the price of success." A necessary part of this vigilance in electrolytic processes must consist in watching the current density and adjusting it to the needs of the moment.

Loss of Heat by Radiation and Conduction.

In any metallurgical furnace the energy required for its operation is in part usefully spent for the production of the necessary physical and chemical reactions, and is partly wasted by loss of heat due to radiation and conduction. Some day metallurgical engineers will reach the same status which has already been reached by electrical engineers, who, in dynamo and transformer design, can predetermine on paper the losses, and therefore the efficiency. It should not be difficult for metallurgists to get practical rules for determining the radiation loss. As a first approximation the outside radiating surface of a furnace is thermodynamically a black body, and the radiation loss is then given by the Stefan-Boltzmann law. The necessity of maintaining the radiating surface on as low a temperature as possible is manifest from this law, since the loss by radiation increases with the fourth power of the temperature. On the other hand, to get rules for the predetermination of the loss of heat by conduction, much more experimental work is to be done. But we note with pleasure that various experimenters are now working in this direction. The recent work of Hutton and Beard (our Vol. III., p. 291) and the experiments of Bied, mentioned in the Synopsis in the present issue, are interesting examples of useful work in this field.

The Outcome of the Detinning Suit.

The long legal battle between the Vulcan Detinning Co. as complainant and the American Can Co. as defendant, has now been decided in favor of the latter. The decision is specially interesting in its references to the history of the electrolytic detinning industry, and also with respect to the protection of secret processes by law.

The decision was rendered by Vice-Chancellor Bergen, in the Court of Chancery of New Jersey, Newark, N. J., and reads in part as follows:

"The evidence in this cause shows that the firm of Th. Goldschmidt, of Essen, Germany, had, prior to 1894, as the result of experiments pursued for that purpose, so perfected a process by which well-known chemical and mechanical principles could be so applied, in the separation and recovery of different metals, as to render the detinning of tin scrap profitable to a degree not theretofore attained.

"The successful combination was not patented, but its inventors sought to protect themselves against infringement by keeping their discovery a secret, only imparting it to such of their employees as the carrying on of the business required, and then only upon a promise not to divulge."

Dr. Hans Goldschmidt is mentioned as the member of the firm most active in making these experiments.

It is stated that "the growth of the business at Essen required the purchase of large quantities of tin scrap, some of which was bought in England and some in New York, the purchases in the latter city being made largely, if not entirely, from A. Kern & Co., a firm engaged in importing and exporting goods.

"The scrap from England appears to have been shipped prior to 1895, through the Zealand Steamship Co., in the employment of which company were M. Laernoes, R. J. Brakema and H. L. Herman, who, through their connection with the Zealand Co., it is fair to presume, acquired some knowledge of the character and extent of the Essen business, for about this time they built a detinning plant at Vlissingen, Holland, under the name of the 'Electro-Tinfabriek,' and through newspaper advertisements, followed by personal interviews, induced two of the confidential employees of the Essen factory * * * to leave their employment, in Essen, and enter the service of the Holland company.

"I have no hesitation in finding that the processes used by Laernoes and his confederates in the Holland factory were, for all practical purposes, the same as that used by the Goldschmidts in their Essen factory. * * *

"The possibility of erecting a detinning plant in this country attracted the attention of Mr. Adolph Kern, the senior member of the firm of A. Kern & Co., as early as 1892, at which time he opened negotiations with the Messrs. Goldschmidt, looking to the establishment of such a plant in America, to be operated according to the processes in use in Essen. The negotiations, carried on principally by correspondence until 1897, produced no satisfactory result, and in December of that year a party of gentlemen, seven in number, of whom the defendant Assman was one, met with Mr. Kern at an office in New York City, to consider the desirability of making further efforts towards the founding of a detinning factory in the United States. * * *

"In furtherance of this conclusion, Mr. Kern first visited the Holland factory, and then went to Essen, where he saw the Messrs. Goldschmidt, and tried to induce them to join in the enterprise, but they refused, giving as a reason that in their opinion the cost of wages and materials in the United States would prevent the successful application of the process in that country. From Essen Mr. Kern returned to Holland, and entered into negotiations with Laernoes, who acted for the Electro-Tinfabriek, of Vlissingen, which resulted in an optional contract, by the terms of which, in consideration of one-third of the capital stock of a company to be organized for the carrying on of the detinning business in the United States, the Holland company were to furnish the processes, etc.

"On his return to this country Mr. Kern submitted to his associates the result of the negotiations he had made in their behalf, and he was directed to accept the option and to procure a formal contract based on its terms. This was done, and Laernoes, with Zeyen, came to this country to supervise the erection of the factory and instruct the purchasers how to operate it. On the arrival of Laernoes the formal contract was prepared and executed between the 'Electro-Tinfabriek' and A. Kern & Co., Laernoes acting and signing as the representative of the Holland firm; thereupon a company was formed under the name of the 'Vulcan Metal Refining Co.'"

Factories were erected in 1898 at Sewarren, N. J., and in 1899 at Streator, Ill. "In 1901, Mr. Assman, having then became a director and officer of the American Can Co., resigned his position with the Vulcan Co., and sold his stock to Mr. Kern, giving as a reason for dissolving his connection with the Vulcan Co., that as the American Can Co. was a large seller of tin scrap to the Vulcan Co., of the selling of which he had charge, he could not consistently continue to occupy the position of buyer and seller. Shortly after Mr. Assman dissolved his relations with the Vulcan Co., the American Can Co. began the erection of two detinning plants, one at Paulsboro, N. J., and the other at Joliet, Ill."

"No reasonable doubt can exist under the evidence in this cause that the methods and processes in use by the defendants, the complainant, Laernoes and his partners, under the name of the Electro-Tinfabriek, and by the Messrs. Goldschmidt, at Essen, are for all practical purposes identical, the changes in mechanical construction being so small and unimportant as to hardly merit consideration.

"The bill of complaint prays that the American Can Co. and the defendants Assman, Baumann, Schmaal and Egbert may be enjoined from operating the detinning plants at Paulsboro and Joliet, or constructing or operating any other factories in imitation of those of the complainant. * * *

"When stripped of all refinements the situation presented is this: Dr. Goldschmidt discovers a secret process for detinning; Laernoes entices Zeyen, a trusted employee, to betray his master, whereby he became possessed of a secret process belonging to another; that secret the complainant purchases under conditions which charge it with knowledge of the wrong committed against Dr. Goldschmidt, thereby helping Laernoes and Zeyen to market their stolen property. It is not to be conceived that a court of equity will stain its hands by contact with such a disreputable proceeding."

"Since the bill of complaint was filed in this cause, the defendants have obtained from the Goldschmidt's a license, executed in due form, permitting them to use their secret in the United States forever, and in Canada for ten years following the date of such license, which was Oct. 17, 1904. This assignment conveys to the American Can Co. a title to this secret process from its discoverer and is superior to any rights which the complainant has."

CORRESPONDENCE.

Optical Pyrometry.

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—The reviewer of the book of Le Chatelier and Boudouard on *High Temperature Measurements* (page 35 of your January issue) brings up the question as to the effect of vapors on the indications of optical pyrometers.

This question has already been dealt with by Prof. Ch. Féry in the use of one of his pyrometric telescopes, in studying the boiling and distillation of zinc, copper and brass in a Moissan furnace. (*Annales de Chimie et de Physique*, Vol. XXVIII.,

p. 428, 1903.) In the case of zinc the superheated vapors caused the radiation pyrometer to read about 120° C. too high (*i. e.*, 1,040° C. instead of 920° C.); while in the case of copper the vapor present apparently lowered the boiling point by 100° C. at 2,200° C.

That such vapors *may* influence the readings of an instrument sighted upon a tube furnace is unquestionable; but there is room for much more work in determining the limitations of this effect.

GEORGE K. BURGESS.

WASHINGTON, D. C.

Specific Resistance of Molten Iron and Steel.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—I desire to call your attention to a grave error in the figure for the resistivity (that is, specific resistance) of molten iron, recently published in your journal, which is evidently a million times too small. As this is perhaps the only figure published of this constant, it seems most unfortunate that it is incorrect.

The figure referred to is given on page 384, first column, of your issue of October, 1905, in the form of an abstract of a note by Mr. Gustave Gin, read before the American Electrochemical Society, on the electric resistivity of iron and steel at high tempertaures. He there gives the results of a determination for cast iron containing about 93 per cent iron and about 3 per cent each of carbon and manganese, and gives as the resistivity "0.00016 microhm-centimeters for temperatures between 1,280° C. and 1,340° C." This figure should evidently be one million times as great, that is, it should either read 160 microhm-centimeters or else 0.00016 ohm-centimeters, or more correctly ohm, cubic centimeter units.

It will appear evident that the figure, as given, is much too small, from the fact that the resistivity of pure copper in those units (namely, microhm-centimeters) is 1.667, and that, therefore, this molten iron would have a resistivity which is ten thousand times less than copper, which, of course, would be too remarkable to be true.

To further demonstrate its incorrectness, I have made a comparison with some other determinations of the specific resistance of iron and steel at very high temperatures, nearly, though not quite, in the molten state. These determinations were made by W. Kohlrausch, and are given in the well-known tables of Landolt & Boernstein, page 468. As they may be of interest to your readers, I reproduce them here. They are there reduced to conductivity in terms of mercury at 0° C. In this unit the figure for electrolytic iron at room temperature is 8.405; at a red heat, 0.8913; at a yellow heat, 0.8196. For cast steel, the composition of which is not given, the figures are as follows: For room temperature, 5.154; at red heat, 1.096; at yellow heat, 0.901; at nearly a white heat, 0.826. It will be noticed from these figures that the conductivity of electrolytic iron diminishes to about a tenth when heated to a yellow heat, and that of cast steel diminishes to about a sixth at a white heat, which means that the resistance of the former increases about ten times and the latter about six times. The resistivity of iron at ordinary temperatures is, roughly, 0.1 in ohm, meter, square millimeter units. Ten times this would be just about the specific resistance of mercury, which in these units is, roughly, 1, hence unless there is a phenomenal and very marked change in the specific resistance between white heat and the melting point, which is not likely, it is safe to assume that the resistivity of molten iron is, roughly, a little more than that of mercury.

Taking the Kohlrausch figures, roughly, as 0.82 for a yellow or white heat, which corresponds to temperatures of 1,200° to 1,300° C., and, therefore, almost exactly those given in the paper by Gin, I find that when reduced to specific resistance it is about equal to 1.15 in ohms, meter, square millimeter units; that is, a column of molten iron 1 meter in length and 1 square millimeter in section, would have a resistance of 1.15 ohms at about those temperatures. If the resistivity given by Gin is increased a million times it would become 1.6 in ohms, meter, square millimeter units, and, therefore, would correspond well with the figure of Kohlrausch for the solid state, but nearly at the melting point; it is, therefore, fair to assume that the figure of Gin should be a million times as great, and that his error apparently consisted in writing "microhms" instead of "ohms." The paper gives the analyses down to five figures, and, therefore, with very great accuracy, and discusses small errors of 1 per cent, and yet in the final result he has made an error of one million.

I have compared your abstract with the original copy of Mr. Gin's paper, and find that the error is in the original paper and not in your abstract of it.

I take this opportunity to express my regret that Mr. Gin did not at the same time deduce another important figure which is so necessary in designing resistance furnaces, namely, the watts per cubic centimeter which are necessary to melt and to keep molten the iron. While, of course, these figures depend largely upon the particular construction of the furnace, yet in all well-constructed furnaces in which the heat radiation can be supposed to have been reduced to a minimum, there would probably be no very great variation in these constants; in any case, however, an approximate figure would be very welcome to designers of such furnaces, as such constants are not yet found in reference books, thus compelling the designer to guess at it. The nature of Mr. Gin's test was such that he could readily have determined these constants without any further tests, as he knew the cross-section, the current and the time.

I hope that the above-mentioned correction will prevent others from being misled by Gin's error, as I was at first, until I noticed the absurdity of the figure.

CARL HERING.

PHILADELPHIA, PA.

A Co-Operative Analysis of a Copper Slag.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—In an article by Mr. Thorn Smith, having the above caption and appearing in the November and December, 1905, issues of this journal, the results obtained by different chemists are tabulated and criticised.

Being particularly interested in copper and zinc determinations, I noted the results and criticisms relative to them more especially. As regards copper, the only statement to which I would call attention is the following: "The precipitation on aluminium is tedious, and a trace or more of copper is almost invariably found in the filtrate." Mr. Smith does not stand alone in this supposition, as I have frequently seen the same observation made by others. In my laboratory the time consumed by this precipitation is from 5 to 7 minutes, and the filtrates show absolutely no copper with hydrogen sulphide. The only reasons I can conceive of why anyone should fail to achieve this result are lack of proper conditions for the precipitation, or oxidation and re-solution of some of the precipitate during the washing. Having no trouble whatever myself, I am naturally forced to the above conclusions. I always add a little hydrogen sulphide water after the boiling and previous to the filtration, and wash the precipitate with hydrogen sulphide water. The added hydrogen sulphide water is to insure complete precipitation and prevent reoxidation. In the great majority of cases it produces no discoloration, due to copper, whatever. When a slight discoloration results it is due to some inattention to details. In any event it is of no consequence, since the copper sulphide is retained on the filter.

Referring to the zinc results, I find the following severe strictures in regard to my method: "The chief cause of the lack of agreement seems to lie in the use of the Von Schulz method. For accurate work this method is worse than useless, and even for satisfactory results it is doubtful if the

method so serves the majority of chemists. A perusal of the results reported to the committee on methods of zinc analysis will soon convince the closest friend of Von Schulz and Low's method what may be expected in everyday work."

Later in the article, Mr. Smith inconsistently remarks: "Not enough results are at hand to criticize the Von Schulz and Low method." This is quite true.

As I am the sole author of the method referred to and have made thousands of determinations by it, the above statements would seem to call for some reply on my part.

To begin with, comparatively few chemists appear to be using my method precisely as I describe it. There seems to be a disinclination on the part of technical chemists to follow any method not their own just as its author dictates. Even my own assistants have to be watched in this regard. Each operator thinks he sees short-cuts or improvements, or some modification "just as good," with the result that the straight method is rarely employed. Thus I have found in a number of instances that chemists claiming to use my zinc method are not, properly speaking, using it at all, and yet the method is forced to suffer the opprobrium due to their inferior work. Whenever my methods are employed in my own laboratory it is because I know of no better technical ones, and I certainly stand ready to adopt something different as soon as it is actually demonstrated that my zinc method is "worse than useless." My assistants can easily make an ordinary zinc determination in 20 minutes, and the repeated assay of prepared mixtures of known composition, containing all the usual constituents of ores, has amply demonstrated the accuracy of their work. Referring to my records I find that the average difference between duplicates in our last ten umpire zinc assays is 0.047 per cent, and the greatest difference is 0.10 per cent. This is "everyday" work. The ores ran from 30 to 60 per cent zinc. Has anyone anything better to offer?

Mr. Smith states, in regard to the zinc in the slag analysis: "Of the ten results reported Nos. 3, 10 and 13 are the best." I observe that No. 10 was the Von Schulz and Low method, and No. 13 "the same as No. 10, probably." I further find that my method was used in only two other instances, Nos. 4 and 14. Referring to No. 4, Mr. Smith states: "In view of the fact that this chemist had difficulty with practically the whole of his work it would hardly be fair to lay the blame for poor work on the method used." Result No. 4 is classed as "fair, but hardly satisfactory."

On the basis of the above results it would seem that Mr. Smith is not justified in the severe criticisms quoted above.

After reading Mr. Smith's article I wrote to him requesting a portion of the slag in question. On its receipt I handed the sample to one of my assistants and directed him to assay it for zinc and copper, giving no other instructions than to simply make one determination in each case.

The following are his results and those of Mr. Smith. In regard to the latter, Mr. Smith states: "Each constituent was determined several times, and in most instances by different methods." My assistant's determinations were made on 0.5 gram of material in each case:

	Copper.	*Zinc.*
Burnett	0.85%	2.91%
Smith	0.81	2.94

In view of the above, and my own extensive experience with both my copper and zinc methods, I feel that I am amply justified in calling Mr. Smith's criticisms in question.

Denver, Col. A. H. Low.

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—I have read Mr. Low's criticism of portions of my report on "A Co-operative Analysis of a Copper Slag," with much interest. Mr. Low's difficulty, or misunderstanding, in regard to the precipitation of copper on aluminium is a common one, and one which all of us are prone to. We are apt to assume that if a particular material is amenable to simple treatment in one locality, that no difficulty will be experienced in a region widely remote, where the nature of the material may be widely different.

Mr. Low further assumes that my statement in regard to the presence of a trace of copper in the filtrate is a "supposition." Neither Mr. Low nor any one else can precipitate the copper from a Ducktown slag in from 5 to 7 minutes, providing a reasonable amount of slag be taken for analysis. Our low mattes, averaging about 20 per cent, cannot be treated in any such time; in fact, 15 or 20 minutes are required.

Like Mr. Low I add hydrogen sulphide as a precautionary measure, and often get no precipitation of copper sulphide. So far as I can see the difficulty lies in the fact that our slag is practically an iron slag, and the large amount of ferric iron prevents rapid precipitation.

Our neighbors, the Tennessee Copper Co., experience the same difficulty. On rich mattes, assaying up to 50 per cent of copper, the time of precipitation is much shortened, perhaps to the time mentioned by Mr. Low. As I seldom have occasion to run these high mattes by this scheme, I am unable to state positively. In all of my statements regarding the slag I assume that a reasonable amount of material is taken for analysis, and I do not consider one-half gram sufficient.

In regard to Mr. Low's remarks on zinc I am somewhat at a loss for a reply. In the issue of the *Engineering and Mining Journal* of Jan. 20, 1906, Mr. C. E. Rueger states: "It is generally conceded by experienced chemists that the ferrocyanide method does not give very concordant results on small quantities of zinc. Mr. Furman, for instance, places the minimum at about 4 per cent zinc, using 1 gram of material."

In my report I did say, as Mr. Low states, "A perusal of the results reported to the committee on methods of zinc analysis will soon convince the closest friend of Von Schulz and Low's method what can be expected in everyday work." But I did not "inconsistently" remark that not enough results are at hand to criticize the Von Schulz and Low method. Even the casual reader can see that my first statement referred to the "zinc committee's" work, while the second applied to my own. I endeavored to do the method justice, so far as the slag was concerned.

Wherever there was any doubt as to whether Von Schulz and Low's method was used I gave them the benefit of it. As Mr. Low states, "each operator sees short cuts, or improvements, or some modification just as good." This is true in all methods of analysis, and accounts, in part, for the many discrepancies in co-operative work. Probably what is known as Von Schulz and Low's method, and commonly used, is not that at all in most cases.

Mr. Low further refers to his records, and states that the average difference between duplicates in ten umpire zinc assays is .047 per cent. That this does not prove the infallibility of his method goes without saying, no more than do duplicate results in determining alumina by difference or iron by titration.

If Mr. Low will carefully read my discussion, or at least that part referring to zinc, he will discover that I did not classify No. 4 as "fair but hardly satisfactory." Reference to the tabulated statement of analyses will show that No. 4 found 4.91 per cent of zinc by Von Schulz and Low's method. In my article I stated that "it would hardly be fair to lay the blame for poor work on the method used." I did, however, classify No. 14 as "fair but hardly satisfactory."

There are several methods of analysis which give first-class results in the hands of the originator, but only fair to poor results in the hands of others. That slight changes in manipulation and neglect of vital points, cause the errors is undoubtably true. I have recently attached my name to a method for the preliminary separation of copper from slag, using a large weight of material, and in view of the fact that but few follow it as instructed and then complain of difficulty, it now seems to me to be a mistake for a chemist to so name a method, however original it may be. Thorn Smith.

Isabella, Tenn.

Ore Dressing by Flotation.

The flotation process, which has achieved a great industrial importance in recent years, especially by its successful application to the treatment of Broken Hill tailings in Australia, is the subject of two recent very interesting Faraday Society papers. The joint authors of one of them are Mr. James Swinburne and Dr. G. Rudorf; the author of the second paper is Prof. A. K. Huntington. We give in the following an account of both papers together.

PRACTICE OF THE FLOTATION PROCESS.

Practice in Broken Hill District.—The operation of flotation processes is concisely stated by Prof. Huntington as follows: "Flotation processes [of the Potter-Delprat type] have been successfully applied in practice in further concentrating the metalliferous portion of certain tailings, *i. e.*, residues which had previously resisted concentration, produced in the treatment of the sulphide ores of the Broken Hill mining district.

"The Broken Hill ores are composed of an intimate mixture of sulphides of lead and zinc carrying silver, with a gangue or non-metalliferous admixture mainly composed of garnets, quartz and rhodonite (silicate of manganese), with small quantities of rhodocrosite (carbonate of manganese), siderite (carbonate of iron) and calcite.

"The following analyses given by the Broken Hill Proprietary Co. in an inquiry in the Supreme Court, Victoria, show the composition of the tailings from the Broken Hill district:

	Broken Hill Proprietary No. 1.	*Block 10 Mine.*	*Central Mine.*
PbS	6.62	5.31	1.18
ZnS	25.37	34.86	37.89
Cu_2S	0.18	....	0.12
FeS_2	2.88	2.58	2.88
FeS (in blende)	2.37	2.25	2.32
FeO	5.61	....	4.76
MnO	11.23	....	9.55
Al_2O_3	6.90	....	4.06
CaO	3.94	....	2.92
Co_2	0.44	1.50	1.40
SiO_2	32.70	....	24.30

"The flotation process consists in adding to the sulphide tailings either a solution of dilute sulphuric acid, say 2½ to 10 per cent in practice (Potter's process), or a solution of acid sulphate of soda (Delprat's process), at a temperature of about 65° C. Under these conditions the metallic sulphides of the ore are floated up by attached bubbles of gas, and form a coherent scum which can be removed, leaving the earthy matter. When carefully carried out the separation is practically a quantitative one."

Ores Suitable for Flotation.—A most important question is, of course, which ores can be treated by the flotation process, and in this respect Messrs. Swinburne and Rudorf give some interesting notes in their paper. While this information is somewhat interconnected with their argument on the physics of the process which will be given below, the results of some tests will be given here which they have made with various ores and sulphides in dilute acid or acid sulphates of soda. Of those tested "the following are most easily floated, in order of merit:

"Molybdenite.
"Stibnite.
"Galena.
"Mixed zinc-lead sulphides, such as the Broken Hill ores.
"Copper glance.
"Zinc blende.
"Iron pyrites.

"The last two scarcely float at all. Copper glance only floats if slightly weathered, and then only in very small amounts.

"With the Broken Hill ores the ratio of the Zn: Pb in the concentrate differs very little from that in the ore, only the gangue being left behind. Galena is fairly easy to float if finely ground, but owing to its rather high specific gravity very fine pulverization is necessary to float it successfully. Stibnite and Molybdenite go quite easily, owing to their very greasy nature.

"We have made a good many experiments with various ores, but do not think it is necessary to go fully into them here. We have, therefore, only given this short list as an example of the way in which things go.

"We also tried some of the gangue obtained from the Broken Hill ores by the Phœnix process due to one of us. This looks like river sand, and consists principally of rhodonites and garnets. Not the slightest flotation was obtained.

"It is interesting to note that ground malachite—copper carbonate—floats fairly well in water. It may be remembered that this mineral has a peculiar greasy feeling. Beyond this we have not found any other carbonates that float.

"This list is only roughly correct, however, and it is most probable, in fact almost certain, that various samples of sulphides differ considerably, and if a slight weathering is necessary to produce the small trace of carbonate needed to give flotation, the 'greasiness' in itself is not sufficient to give the separation. It is, in fact, quite impossible to tell beforehand which ores can be separated by flotation."

NATURE AND ORIGIN OF THE GAS CAUSING FLOTATION.

The first question to be answered is: What are the gas bubbles which lift the sulphide particles and where do these gas particles come from?

Nature of the Gas.—As Messrs. Swinburne and Rudorf point out, "the explanation generally given is delightfully simple. It is said that the acid liberates hydrogen sulphide from the sulphides, and the gas then sticks to the particles and carries them up. As the acid does not act on the gangue, which in such cases is largely silicious material, the gangue is not carried up, and thus the separation takes place.

"This theory does not fit the facts. In the first place, the sulphides generally treated are not attacked by the acid solution, so that there is no hydrogen sulphide evolved; or, at most, it is given off in very small quantities, which are out of all proportion to the amount of material floated. The sulphides of zinc, iron and manganese alone are attacked at all by dilute acids. It cannot, therefore, be the hydrogen sulphide that carries up the particles of sulphide. On the other hand, there is a considerable evolution of gas, but it is carbon dioxide, and carbon dioxide is chiefly given off by the gangue, which generally contains calcite and other carbonates, the carbonates being mostly produced by the weathering of the sulphide particles. According to the theory just given, this action, contrary to what is actually found to be the case, ought to float up either the gangue as a whole, leaving the sulphides, or it should at least float up the carbonates. The next point is that in most cases flotation does not take place at all until the temperature approaches boiling point."

Origin of the Carbon Dioxide.—Prof. Huntington in his paper starts right away with the statement that it has been shown beyond question that the gas causing flotation is CO_2, and then discusses where it comes from.

"It was at first assumed by some that the CO_2 was derived from calcite, and by others that it came from carbonates, produced on the surfaces of the sulphides by 'weathering.' This latter supposition cannot be correct, because the Broken Hill ores at present mined are obtained from a depth below the water level, and on examination have been found to be free from 'weathering.' On going into the matter I was able to prove that the CO_2, which gives rise to the flotation, is liberated mainly from the rhodocrosite and siderite, and certainly not from the calcite."

For this purpose Prof. Huntington made a flotation experiment with Broken Hill "Block 10" tailings, using a H_2SO_4 solution. So soon as the flotation had proceeded as far as it

could go (about 2 minutes) the solution was separated from the tailings and analyzed for the Fe, Mn, Ca, Zn and Pb which had passed into solution.

The following is the result calculated as carbonates:

	Per Cent.
$FeCO_3$	1.30
$MnCO_3$	1.85
$CaCO_3$	0.15
$ZnCO_3$	1.27

It will be observed that the quantity of $CaCO_3$ is very small, but, of course, that might be due to the slight solubility of $CaSO_4$. Another experiment was, therefore, made by Prof. Huntington in which HCl was used instead of H_2SO_4, with the following result:

	Per Cent.
$FeCO_3$	1.87
$MnCO_3$	1.61
$CaCO_3$	0.55
$PbCO_3$	1.20

Zn not determined.

Here, again, the $CaCO_3$ is very little, although $CaCl_2$ is very soluble. The merest trace of sulphuretted hydrogen, if even that, is given off.

"In a 5 per cent sulphuric acid native iron carbonate is not acted on until a temperature of about 65° C. is reached, which is the temperature at which flotation takes place with the sulphide ore. Carbonate of manganese behaves in a similar manner. If either be added to sulphide tailings, from which the CO_2 has been removed by previous exhaustion with acid and washing without drying, and acid or acid sulphate be added, as good a flotation is obtained as with the tailings from which the CO_2 had not been removed.*

"Carbonate of lead gave no flotation, the action of sulphuric acid on it being very feeble, owing to the formation of an insoluble coating of lead sulphate.

"Zinc carbonate, when added to sulphide ore, is readily acted on in the cold, and practically gives no flotation of sulphides with either a cold or a hot solution. Owing to the crushed native carbonate being light and spongy, it floats in the solution and generates the gas there rather than on the ore. So far as I could judge, if naturally present in the ore, it would give, if any, a very unsatisfactory flotation, which is characteristic of carbonates decomposed in the cold. Sodium carbonate gives no flotation, but separates the sulphides and the gangue into two layers, and calcium carbonate, although it gives a certain amount of flotation, does not give rise to a true scum, but only to a floating, spongy material, the remainder of the sulphide falling back on to the top of the gangue. A sample of yellow dolomite, when treated with H_2SO_4, gave off some CO_2 at about 30° C., and at about 40° C. the sulphides of the tailings (previously exhausted of CO_2 and washed with alcohol) were lifted, but no coherent scum was formed, the sulphides falling back.

"A copper ore veined with $CaCO_3$ on slightly warming (it was a very cold day) gave off abundance of CO_2, and the finer particles of sulphide floated without, however, forming a good and permanent scum. After the CO_2 had all been exhausted the whole of the sulphide was easily floated by adding $FeCO_3$.

"It has been stated that tailings can be exhausted of CO_2 by the action of acid in the cold. The following experiment was made, which does not bear out this statement, and goes to corroborate the other evidence that the CO_2 is not derived from calcium carbonate:

"Twenty grams Broken Hill tailings and 25 cc. H_2SO_4 (5 per cent) were placed in a flask fitted with a cork and delivery tube dipping into paraffin. No gas was evolved in 24 hours, and on decanting off the liquid and heating no gas was obtained. On adding fresh acid to the residue and heating a normal flotation occurred.

"It has also been suggested that the reason why the flotation does not take place until the temperature has been raised, is that the Co_2 is at first absorbed by the solution. I have made an experiment in which the solution was first saturated with CO_2, but it made no difference, the flotation did not begin until the usual temperature was reached.

"I have also shown experimentally that only acids which attack carbonates of iron and manganese are any use, and that this only takes place in a hot solution.

"I find, however, that sulphur or graphite mixed with calcite and treated with H_2SO_4 in the cold completely float, even when these bodies have been previously thoroughly wetted by grinding them with glycerol.

"These experiments, coupled with the fact that $CaCO_3$, does not give good flotation with tailings exhausted of CO_2, is enough to show conclusively that $CaCO_3$ is not the source of the CO_2, causing flotation of the Broken Hill sulphide tailings. Beyond that we have the fact that no carbonate which is decomposed easily in the cold gives good flotation, or indeed flotation at all, with the exception of $CaCO_3$, which gives a poor flotation. Crystalline $FeCO_3$ and $McCo_3$ are, in fact, the only carbonates which give flotation with a true coherent scum. $FeCO_3$ and $MnCO_3$ in the precipitated amorphous condition do not give any flotation. In that state they are easily decomposed by acids in the cold.

"Experiments were likewise made to obtain flotation with CO_2 by using a solution into which it had been compressed, the solution being finally warmed. Success did not attend the attempts to float sulphides in this way."

Prof. Huntington feels justified, therefore, in assuming that the effective CO_2 in the flotation process, as applied to Broken Hill tailings, is derived from minerals composed of crystallized carbonates of iron and manganese.

Theory of the Flotation Process.

Swinburne and Rudorf's Capillary Theory.—Messrs. Swinburne and Rudorf consider that the whole matter is mainly a question of capillarity. Two distinct capillary forces come into play at the boundary surface of the solid and the liquid. The first one is adhesion, that is attraction between the solid and the liquid particles; it is measured by the contact angle between the surfaces of the liquid and solid. The second is cohesion, that is the attraction between the liquid particles themselves, as measured by the surface tension. "Greasy" substances are those for which the cohesion of the liquid is greater than the adhesion of the liquid to the solid. Greasiness seems to be intimately connected with the formation of a gas film or air film on the surface. The degree of greasiness increases with time as the gas film gets thicker.

To apply these conceptions to the explanation of the flotation process it is necessary to explain with their aid why are the sulphides selected by the gas bells to be floated, and why does the temperature matter?

Let us consider a particle of ore and the gas bell. The surface tension of the liquid tends to make the surface of the liquid as small as possible consistently with its still containing the air or gas. If the particle has no adhesion the surface of the liquid surrounding it must be considered as part of the surface which has surface tension, so that this surface will arrange in such a way as to be the least possible while including both the gas and the particle. If the particle is large in proportion to the gas bubble the surface will surround it, the gas will fill up any inequalities and allow the surface to take the spherical form. If the particle is small the result will be a gas bell with a particle nearly inside it. This is the effect of cohesion.

* Cleveland oolitic carbonate and other specimens of clay ironstone give a very poor flotation with Broken Hill tailings. The sulphides distinctly separate from the gangue, but will not float to the surface. This is probably due to the presence of the clay. But graphite floats perfectly after being washed with alcohol, when Cleveland ore and acid are added.

On the other hand, adhesion tends to increase the contact surface between the solid particle and the liquid so that the particle is more and more immersed in the liquid until, with increasing adhesion, the gas bell is detached.

In order to make particles of ore float up, it is necessary to get gas bells that will stick and not detach. Most constituents of ores have too great adhesion for water or dilute acid to be floated, and to float them it is necessary to diminish the adhesion between solid and liquid. This can be done by increasing the temperature. Raising the temperature reduces both adhesion and cohesion, but while the surface tension vanishes only at the critical temperature, the adhesion appears to vanish about the boiling point. By raising the temperature near the boiling point, the adhesion is therefore sufficiently reduced for the surface tension to overcome it, and the attached gas bells then lift the particles. Even then particles with small adhesion will alone be raised. This explains the effect of temperature.

The phenomenon of adhesion seems to be intimately connected with that of the air-film. Surface tension produces an extra pressure on the gas in a bell, and if the bell is very small the pressure is very great, so that it is difficult for the bell to start. The air-film may give it a chance of starting.

The difference of adhesion of various minerals to dilute acid or water is considerable. Thus galena is more difficult to wet than silica, and so on; and those ores alone can be concentrated by flotation "whose valuable constituent is some greasy sulphide such as galena, or at most so automatically attached to the greasy sulphide that it comes off with it. Zinc sulphide is thus easily raised by galena when intimately associated, as in the Broken Hill and some of the Vieille Montaigne Co.'s ores.

"It is not enough to have the greasy particles; it is necessary to produce the gas bells and get them against the particles. In practical work the only gas that comes off is carbon dioxide, and this appears to come largely from calcite. But mixing calcite with an ore which has a greasy constituent will not necessarily float it; the gas is apt to come away from the particles of calcite without getting attached to the ore. It seems much more likely that the gas that really effects the flotation is generated by the action of acid on small quantities of carbonates produced by a slight weathering of the ores. It is most likely due to small amounts of carbonate of iron and manganese. These carbonates are also not attacked by dilute acid in the cold."

Huntington's Suggestions of Electrostatic Action.—Prof. Huntington points out that the flotation process must either be considered to be due to surface tension phenomena or to electrostatic attraction. While he does not maintain that the latter explanation would hold, yet he makes some interesting suggestions concerning it. He has found experimentally that the CO_2, as it rises, carries a positive electric charge with it while the solution gets negatively charged; the negative charge of the solution can be shown by an electrometer connected with the containing vessel only if the gas leaves the solution, taking the positive charge with it. Prof. Huntington also has established that the gas or the fog in the bubble gives up its charge very slowly, and cannot therefore be easily neutralized. He then made experiments to see whether it is possible to make the sulphides float by means of air or CO_2, passed through the sulphides with or without previous electrification. No perceptible selective flotation was obtained in either case, and he was unable to ascertain whether the surface tension of the liquid in contact with the sulphides was influenced by electrification. In other words, while he established that electrification occurs, yet he was unable to obtain any evidence that it plays any part in the flotation.

Huntington's Criticism of Swinburne's and Rudorf's Theory.—Prof. Huntington criticises the assumption of Swinburne and Rudorf of the presence of an air-film on the surface of the sulphide particles; he found that the particles were floated perfectly after he had taken great care to remove the adherent film of gas by exhaustion with acid, washing with alcohol, treatment with air-free distilled water and exhaustion with the pump, etc. He remarks that flotation depending on the presence of an adhering film of air is made use of in certain suggested concentration processes, which, however, are different in principle from those under consideration. In these processes the ore is brought very carefully on to the surface of the water, so that the gangue or easily wetted portion may sink and the sulphides which are not well wetted may remain floating. What is aimed at is to prevent the sulphides from sinking, which is a different thing to making them float up from the bottom.

It is a curious fact that specimens of zinc blende containing but little gangue, which do not form a scum on treatment with sulphuric acid and carbonate of iron, give an excellent flotation if previously mixed with sand. On the other hand, too great dilution with inert matter injures the flotation. The Broken Hill vanner tailings appear to be ideally suitable for the flotation process. Prof. Huntington thinks that "these experiments dispose of Messrs. Swinburne and Rudorf's contention that blende scarcely floats at all, and incidentally of the statement that zinc blende is thus easily raised by galena when intimately associated. Swinburne and Rudorf themselves admit that galena has to be very finely pulverized to float successfully; it is different, therefore, to see how it could be expected to float with attached inert blende. It appears more probable that the blende helps the galena to float. This view was strengthened by some experiments made on the wetting of sulphide surfaces.

The degree of wetting of a surface may be judged by measuring the angle which the liquid makes with it. Direct determination of this angle for different minerals by a goniometer method are described, the values obtained varying from 47° to 63° for different sulphides. Quartz and magnetite are completely wetted by water. Alcohol wets all sulphides, but on again placing in water the apparent "greasiness" is restored.

When a gas bubble comes into contact with a mineral particle, the extent of surface of the bubble which will be in contact with the solid depends on the angle of contact of the solid with the liquid. If the angle is such as to cause a relatively large surface of the gas to be in contact with the solid, and the bubble is sufficiently large, the particle will be floated. The less the wetting the greater will be the force required to detach the bubble. If the surface of the solid is wetted the bubble has no attachment at all.

Swinburne and Rudorf on the Action of Different Solutions.—As was already mentioned, Potter originally used dilute acid, preferably sulphuric, of about 2 per cent strength, while a saturated salt-cake solution is employed by Delprat. Messrs. Swinburne and Rudorf have found that generally the latter solution works rather better than the former.

"With salt-cake solution the bubbles get larger than with dilute acid and rise more slowly, owing to the greater density and viscosity of the former solution. Certainly a much more stable and compact scum is formed when salt-cake solution is used, and this is no doubt due to the viscosity of this solution, but more especially to the surface viscosity which is always greater than the ordinary viscosity or internal friction. It is well known that bodies on the surface of a liquid attract one another if all be wet or all be dry. If one particle be wet and another dry then there is repulsion between them. The compactness of the scum in the case of salt-cake solution is, therefore, most likely due to the fact that the particles, on account of the increased surface viscosity as compared with dilute acid, tend to keep drier than with the dilute acid, and, therefore, attract one another, forming a compact scum. It need hardly be pointed out that this apparent attraction is really a surface-tension phenomenon again. If particles of dry sand rest on water, each produces a little dent in the surface and increases its area. The increase of area of the tense surface is least

when the particles are all together, making one big dent. This holds good—to a less extent—with greasy particles floating, and with completely wet particles. With wet particles the dents become prominences, but the surface action is otherwise the same."

Both papers were presented at the same meeting of the Faraday Society, and elicited considerable discussion, an account of which is given by our London correspondent in his monthly letter, published on another page of this issue.

Refractory Uses of Bauxite.

By A. J. Aubrey.

Bauxite is a hydrated oxide of aluminium corresponding to the chemical formula $Al_2O_3 \cdot 2H_2O$, although the proportion of water varies greatly and the aluminium is sometimes replaced by iron. Silica and titanium oxide occur as impurities. The silica varies widely in different deposits. Other oxides of aluminium containing water are diaspore ($Al_2O_3 \cdot H_2O$), and gibbsite ($Al_2O_3 \cdot 3H_2O$). These are found in small quantities, however. The andydrous oxide of aluminium, known as corundrum (Al_2O_3), is found in still smaller quantities than the above, so that bauxite is the only oxide of aluminium found in considerable quantities. There are three localities in the United States where bauxite has been found in commercial deposits, viz.: in Arkansas, New Mexico and the Georgia-Alabama district. The last-named district has probably been worked out by this time, and at present the chief sources of the ore are the Arkansas deposits.

The crude bauxite is washed at the mines to remove some of the free silica. It is next calcined at a temperature of 2,500° F., approximately Seger cone 12, and during this process it gives off its chemical water, amounting to about 30 per cent of the raw ore, and also undergoes great shrinkage. It has been observed that the bauxite shrinks very little until after Seger cone 9, approximately 2,390° F., is reached, and from Seger cones 9 and 12 the greatest amount of the shrinkage takes place. Accordingly the lowest temperature limit at which bauxite should be calcined is 2,500° F.

An analysis of washed calcined bauxite from Arkansas made by the writer is as follows:

	Per Cent.
Mechanical water	0.88
Silica	6.40
Fe_2O_3	1.43
Alumina	87.30
TiO_2	3.99

The calcined material can be bonded with fire-clay, sodium silicate or lime, and made into brick and tile. As little as 4 per cent plastic fire-clay can be used for a bond for hand-made brick. When bonded with lime the brick becomes quite hard a few hours after making, so hard that they will not take the impression of the finger nail. This setting or hardening is probably due to the formation of a calcium silicate between the lime and the free silicia analogous to the setting of silica brick when bonded with lime. After a careful drying treatment the brick are burned in down-draft kilns at a high temperature, and when burned they are hard and tough and can be thrown to the pavement or batted vigorously against one another without breaking. A brick 9 inches x 2½ inches x 4½ inches weighs 7.5 pounds, and stands a crushing test of 10,000 pounds per square inch.

The problem of calcining the washed granular bauxite presents itself. It cannot be successfully calcined in a vertical shaft kiln, because it will pack and clog on account of its fineness, and so obstruct the passage of the kiln gases. On the other hand, it is not feasible to calcine it in the ordinary down-draft kiln on account of the perforated floor. The writer believes that to calcine it on a commercial scale would require a rotary kiln using oil, gas or powdered coal for fuel, preferably the former. Provided the cost of fuel is low at the mines these kilns should be installed there in order to save the cost of transportation, which is now paid on the 30 per cent of water that the crude bauxite contains.

Steel Furnaces.

For basic open-hearth steel furnaces a brick high in alumina and low in silica is required. A brick of this character is obtained in the following way: A pure white variety of the pisolitic bauxite, which has already been washed at the mines and a portion of its free silica removed, is selected and sieved. All the fine material passing through the sieve is rejected, as it contains the greater part of the silica. The pisolities, or pebbles about the size of peas, are retained, as they are higher in alumina and freer from silica than any other part of the bauxite. Now, by using lime selected for its freedom from silica, as a bond, a brick can be procured which will contain as low as 6 per cent or 8 per cent silica.

A high silica content has always been the chief objectionable feature of bauxite brick for basic open-hearth steel furnaces, because the silica is attacked by the basic slag. Authorities on open-hearth practice have generally declared that bauxite brick would be suitable for basic open-hearth furnaces, provided a brick could be made with less than 12 per cent silica content. And, indeed, recent tests made along this line seem to bear out this statement.

A test was made several months ago in one of the basic open-hearth furnaces of the Bethlehem Steel Works, in which a bauxite and a magnesite brick were placed side by side near the gas and air ports, and submitted to the highest temperatures attainable in the furnace. The magnesite brick bent and showed viscosity after a period of 7 minutes against a period of 15 minutes for the bauxite brick. Again, a magnesite brick and bauxite brick were bathed in the slag near the doors for a period of some time, after which they were withdrawn and examined when cold. The magnesite brick was incorporated with slag while the bauxite, when broken open, showed that the slag had not penetrated to its center but had remained as a coating over the outside. Both bricks were quite badly affected, but it was readily apparent that the bauxite withstood the action of the corrosive slag equally as well as the magnesite.

More recent tests with brick having a lower content of silica have shown up equally as favorable as the magnesite when exposed to the action of the basic slag. The comparison is hard to make in any case, because of the fact that either bauxite or a magnesite brick, if left in the hearth of the furnace for any length of time submerged in the slag, are so violently attacked that the differences in the portions that are taken out are not easily detected. Even a magnesite brick if thrown into a basic open-hearth furnace will be entirely eaten away after considerable length of time, so that the only real test of bauxite brick will be to build a hearth, or portion of hearth, out of these brick and test them, covering them with calcined bauxite and treating them in every way like the magnesite hearths are treated. Some steps are now being taken towards accomplishing tests of this character.

Sir William Siemens found that bauxite was a superior furnace lining, and even though he used an inferior bauxite, containing as much as 35 per cent oxide of iron, he claimed they lasted five or six times as long as the "Stourbridge First Brick." Siemens also says of bauxite: "It is important to observe that bauxite when exposed to intense heat is converted into a solid mass of emery, of such extreme hardness that it can hardly be touched by steel tools, and is capable of resisting mechanical as well as the calorific and chemical action to which it is exposed."

Bischof, in his "Feuerfeste Thone," says that bauxite "when not impure on account of the admixture of foreign substances,

especially of iron, which generally occurs in considerable quantities in compounds of aluminium, is extremely refractory." He also goes on to say that "the addition of varieties free from iron, or the white ones, to other refractory clays offers the only important means known of increasing their percentage of alumina, and at the same time their refractoriness."

It appears then that bauxite has been regarded as a refractory material for a long time, but that no definite use has been made of it, also that the inferior grades have been more generally tested than the purer ones.

Aside from its use for open-hearth furnaces, which, by the way, is being thoroughly exploited and investigated to make certain of its fitness before taking any risks, bauxite brick have shown up quite successfully in other lines.

Two recent applications are its uses: first, as a lining for rotary Portland cement kilns, and second, as a lining for lead refining furnaces.

LINING FOR ROTARY PORTLAND CEMENT KILNS.

As a lining for a rotary Portland cement kiln it has shown unusual durability and has given excellent service. As an experiment, the hot zone (about 10 to 12 feet) of a 60-foot rotary kiln fired with coal dust, was lined with a 6-inch bauxite lining, whereas the kiln had previously been lined with a 9-inch fire-clay block.

A block for lining rotary Portland cement kilns in the hot zone must possess the following qualities: It must neither be too hard nor too soft, for if too hard it will not allow the cement coating to stick to the surface, and if too soft it will not hold the coating, but the latter will pull off, bringing portions of the brick with it. The cement coating affords an excellent protection for the lining, and if brick do not hold this coating they soon burn out. The bauxite block made for this purpose has all of the aforesaid qualities.

After ten months of continuous service night and day this 6-inch lining is still doing the work. The loss of output in cement for every 24 hours that one of these rotary kilns is shut down is equivalent to the sum of $250. As the minimum time required for lining or patching a kiln in the hot zone is from 36 to 48 hours, one can easily estimate that the loss of output will be equivalent to a sum varying between $375 and $500. In this case it is quite apparent that a superior lining will be the cheaper in the long run. Again, it must be remembered that only the hot zone need be lined with a bauxite block.

LEAD REFINING FURNACES.

The second and most recent application of bauxite brick has been that of lining portions of lead refining furnaces.

Pig lead, containing copper, antimony, and occasionally arsenic and other metals in small quantities, is charged into the hearth of the refining smelter and melted by the reverberation of hot gases from above.

The hearth of the furnace, which is 10 by 13 feet in dimensions, is lined on the bottom by 9-inch square brick set on end. The sides of the furnace are lined with a single course of 9-inch brick laid with ends against the walls.

The temperature of the furnace is from 1,300° to 1,400° F., and outside of the part it plays in melting the fluxes bears no relation to the destruction of the brick, as they are sufficiently refractory to withstand much higher temperatures. It is purely a case of chemical action on the brick.

During the process of refining, a scum rises to the surface of the molten lead, and this scum contains most of the impurities which the refining is designed to remove. It consists largely of litharge, or yellow oxide of lead, PbO, copper oxide CuO, and antimony oxide Sb_2O_5, with possibly other oxides in much smaller amounts.

Wherever the brick are exposed to this scum, particularly around the doors, where there is a larger supply of oxygen, and accordingly litharge is more easily formed, and along the level of this scum, on the walls, they are badly eaten away and have to be taken out after several weeks service, and generally have to be patched after a week has passed. Consequently the furnace loses much time for repairs, which lowers its output considerably.

The cutting away of the brick is explained as follows: Multiple silicates are formed between the oxides of the metals in the scum and the silicates of alumina and free silica in the brick, and these are very fusible, because lead oxide, PbO, which is one of the most fusible of the oxides, comprises the greater part of the base or RO element of the silicate. But there are also several other oxides in the base of the silicate, and it is quite well understood that multiple are more fusible than single silicates.

Hence, as very fusible silicates are formed between the scum and the fire-brick the brick are very rapidly decomposed and eaten away. It was observed that a porous brick wore out faster than a dense brick, also that the scum penetrated along the joints for several inches beyond the exposed face of the brick. This was probably due to the fact that the raw fire-clay which was used in making the joints is much more soluble in the scum than the burnt clay. Accordingly great care should be taken in laying up the brick to see that the joints are as tight as possible.

Whereas, the scum was composed of highly basic oxides, it was considered reasonable to supplement a basic lining for the fire-brick lining, and accordingly a lining of bauxite was put in wherever the brick were exposed to the slag. The result was that the bauxite brick lasted from five to six times as long as the fire-brick lining.

With the above-mentioned uses and its possible advent into open-hearth practice elsewhere, the writer feels that bauxite brick will at some early future date comprise one of our most valuable and useful refractory materials.

Laclede Fire-Brick Mfg. Co., St. Louis, Mo.

The Carborundum Furnace.

BY F. A. J. FITZGERALD.

When a mixture of silica and carbon is heated to a sufficiently high temperature the silica is reduced, and if a proper amount of carbon is present silicon carbide is formed, according to the following equation:

$$SiO_2 + 3C = SiC + 2CO$$

At relatively low temperatures the silica-carbon mixture yields a greenish-colored amorphous substance, but as the temperature is increased this is converted into crystalline silicon carbide, which has been named "carborundum" by its discoverer, Mr. E. G. Acheson. If the temperature is increased considerably beyond that of its formation, carborundum is decomposed, the silicon being expelled as vapor and the carbon left behind in the form of graphite. Moreover, this decomposition takes place without fusion of the carborundum, and the graphite is left as a beautiful pseudomorph of the carborundum crystals.

The physical properties of carborundum suggest at once that a special form of furnace is necessary for its manufacture. Since it is infusible the furnace cannot be tapped as in the case of calcium carbide, and it is, therefore, difficult to devise any method by which the manufacture of carborundum could be made a continuous process. Moreover, since it is easily decomposed at very high temperatures it is necessary that there be some means of regulating the temperature of the furnace so that this is kept between the limiting temperatures of the formation and decomposition of silicon carbide. This condition indicates that an arc furnace would be unsuitable, for while it is undoubtedly possible to produce carborundum in a furnace heated by an arc, it would not be a practical or efficient method of manufacture. No doubt an arc may be used

in the production of substances that are vaporized or decomposed at the temperature of the arc itself, for as fast as these are formed they may be drawn off from the high-temperature zone; but, as we have seen, that is not feasible in the case of carborundum.

In the earliest form of carborundum furnace an arc was used, the furnace charge surrounding two carbons, between which an arc was drawn. This, however, was soon abandoned for a furnace in which the charge was heated by means of a suitable resistor.

For a fairly complete description of carborundum and its manufacture the reader is referred to *Carborundum-Monographien uber angewande Elektrochemie*, Band XIII., from which publication the following description is derived:

Fig. 1 is a diagrammatic sectional plan, and Fig. 2 a transverse section of a carborundum furnace having a capacity of

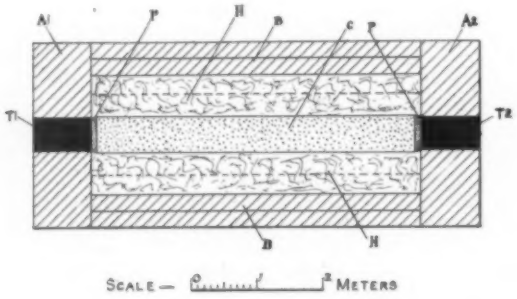


FIG. 1.—SECTION OF CARBORUNDUM FURNACE.

750 kilowatts. A1 and A2 represent the end walls of the furnace, and carry the carbon terminals T1 and T2 respectively. The end walls are permanent structures, unlike the side-walls B, B, which are rebuilt every time the furnace is run. C is the resistor, or "core," composed of granular coke, and is electrically connected with the terminals T1 and T2 by the packing carbon P. The resistor is surrounded by the charge H. The broken lines in each figure indicate approximately the distance from the resistor of the carborundum formation.

The terminals of the furnace consist of twenty-five solid carbons, 860 mms. long, and with a cross-section of 100 x 100 mms. The carbons are set in five horizontal rows of five carbons each, and between each row is a copper plate, which serves to connect the terminal with the cables carrying the current. When a furnace is to be charged the side walls are first built up, and the mixture is then thrown into the furnace until it is rather more than half full. Pieces of sheet iron are set up in a vertical, transverse position a few centimeters from the ends of the terminal carbons, in order to keep the mixture from coming into contact with these. This is done because the space between the pieces of sheet iron and the carbons must be filled with finely powdered coke, which forms the "packing carbon" that makes electrical connection between the terminals and the resistor. Then a semi-circular trench, having the diameter desired for the resistor, is formed between the pieces of sheet iron at either end of the furnace. This trench is filled with granular coke, and then as much more of this material added, so that when rounded off on top the resistor has the form of a cylinder extending from one piece of sheet iron to the other. The packing carbon is put between the sheet iron and the carbon terminals and tightly rammed into place, after which the sheet iron is removed. More mixture is thrown into the furnace and it is ready for the current.

The theoretical considerations discussed in a former article[1] apply directly to the carborundum furnace, which consists essentially of a cylindrical resistor surrounded by the material to be heated. If the radius of the resistor is p, its length L and temperature Θ, and if the temperature of the inner surface of the cylinder of surrounding material is Θ_1, then we have for the quantity of heat C flowing from the resistor per second:

$$C = 2\pi pL\ (\Theta - \Theta_1)\ A \qquad (1)$$

where A is a constant, and the assumption is made that there is no flow of heat from the resistor to the terminals of the furnace. From equation (1) we have

$$\Theta_1 = \Theta - \frac{C}{2\pi pLA} \qquad (2)$$

If the furnace is to be used for a current of W watts then

$$C = JW \qquad (3)$$

where J is a constant, and substituting this value for C in equation (2) we have

$$\Theta_1 = \Theta - B\frac{W}{2\pi pL} \qquad (4)$$

Now, when it is considered that the temperatures of formation and decomposition of carborundum have a certain value it is plain that for a given value of W it is necessary to adjust the radiating surface ($2\pi pL$) of the resistor, so that at no time Θ_1 will be greater than the temperature of decomposition of carborundum. On the other hand, the value of $2\pi pL$ must not be so great that Θ_1 will be below the temperature of formation of carborundum.

After a cylinder of carborundum, having an external radius p_1, is formed, and if the temperature of the outer surface of this cylinder is Θ_2, the quantity of heat C_1 passing through the cylinder per second is

$$C_1 = \frac{2\pi LK\ (\Theta_1 - \Theta_2)}{\log \frac{p_1}{p}} \qquad (5)$$

where K is the heat conductivity of the carborundum cylinder. In the carborundum furnace the rate of generation of heat is kept constant, since W in equation (1) is constant, hence, if C is greater than C_1 there will be a progressive increase in Θ_1, until finally a temperature is reached at which carborundum is decomposed.

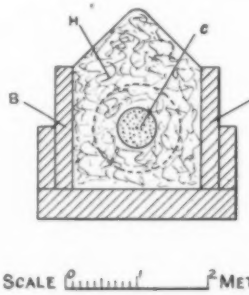


FIG. 2.—TRANSVERSE SECTION OF CARBORUNDUM FURNACE.

Without going into more detail it is evident that the consideration of the theory of the carborundum furnace is of importance in its design.

From the theoretical consideration it may be readily deduced that as the carborundum cylinder increases in size the efficiency of the furnace diminishes, since the heat losses become greater, so that after a cylinder of a certain size is formed it is no longer economical to run the furnace. At all times it is necessary to preserve a fairly thick layer of unchanged mixture outside the carborundum cylinder, since it forms a fairly efficient heat insulator. When the current has been cut off from the furnace this unchanged mixture is removed, until a greenish-colored amorphous substance is exposed. This is an intermediate product in the formation of carborundum, and after he had treated it "with hydrochloric acid, caustic soda, water, hot oxygen and hydrofluoric acid" was found by Muhlhaeuser to have the following composition[2]:

[1] Electrochemical Industry, Vol. II., No. 9.

[2] "Journal of the Franklin Institute," September, 1893.

C	27.93
Si	65.42
Fe_2O_3 and Al_2O_3	5.09
CaO	0.33
MgO	0.21
	98.98

This substance lies immediately outside the carborundum cylinder, and is only a few centimeters thick. The carborundum cylinder, on the other hand, is about 35 centimeters thick, according to the published information on the subject[3], which indicates that the temperatures of its formation and decomposition lie very much further apart than do the temperatures of the formation of carborundum and that of the formation of the amorphous material. In considering this, however, the relative heat conductivities of the two substances would also have to be taken into account.

When the crystalline cylinder is removed from the furnace the granular coke, forming the resistor or core, is found to be graphitized. The graphitized coke may be used as the core of another furnace, and will, of course, have a much lower resistance than a resistor made of ordinary coke. When a furnace is built with a resistor of ordinary coke it is necessary to use a high voltage at the start, and even then it may be some hours before the furnace comes to load. Then follows a great reduction in the resistance, due not merely to the heating of the carbon, but also to its conversion into graphite. The variable voltage is obtained by means of apparatus described in another article[4].

Prof. J. W. Richards has attempted to estimate the efficiency of the carborundum furnace[5]. He defines the efficiency as the ratio between the heat used in bringing up the charge to the reacting temperature plus the heat absorbed in chemical reactions and the total heat generated by the current. The temperature of the furnace is assumed to be 3009° C., and assumptions as to specific heats are also made. From these data the heat necessary for raising the charge of the furnace to the required temperature is calculated, and found to be 42 per cent of the heat energy generated. The heat required for the chemical reaction is calculated as 34.5 per cent, so that the efficiency is 76.5 per cent. Unfortunately, Prof. Richards has failed to take into account the amorphous material that is also formed in the furnace. According to Muhlhaeuser's analysis we may regard this as being amorphous silicon carbide, and in a furnace such as Prof. Richards has assumed the production of this substance may amount to 14 per cent of the carborundum. Moreover, in actual practice it happens almost invariably that a considerable quantity of the carborundum formed in the furnace is decomposed, and this has not been taken into account in the calculations. Finally, the mixture always contains a large quantity of saw-dust, and usually a considerable quantity of water, of which no account is taken. Under these circumstances it is very doubtful if 76.5 represents the efficiency of the carborundum furnace.

In the present state of our knowledge of the working of electric furnaces it is not possible to make even approximate estimates of absolute efficiency, and we must, therefore, be content to compare production and energy. Thus, in his paper before the Franklin Institute in 1893[6], Mr Acheson said he was using 9 kilowatt hours to produce 1 pound of carborundum. According to Prof. Richards, the Carborundum Co. in 1902 produced 7,000 pounds of carborundum with an expenditure of 36,000 hp-hours, that is, 3.8 kw-hours per pound.

[3] "Journal of the Franklin Institute," February, 1897.
[4] Electrochemical and Metallurgical Industry, Vol. III., No. 1, p. 9.
[5] Transactions of the American Electrochemical Society, Vol. II., p. 67.
[6] "Journal of the Franklin Institute," September, 1893.

The American Institute of Mining Engineers will hold its next meeting at Bethlehem, Pa., from Feb. 21 to 23. A feature will be a visit to the Hazard works of the New Jersey Zinc Co.

Metallurgical Calculations.

BY J. W. RICHARDS, PH. D.
Professor of Metallurgy in Lehigh University.

CHIMNEY DRAFT AND FORCED DRAFT.

In all problems concerning combustion, we must furnish the air needed for combustion either by suction or by pressure. The original and almost universal method is by chimney draft; the more positive and reliable method is forced draft. Often the two are combined with very satisfactory results.

The waste heat from any metallurgical process or furnace is generally considerable. Most furnaces must be kept above a red heat, and the gases pass directly out of the furnace into the chimney. In such cases the chimney is indicated as the proper source of draft, because it utilizes, although very inefficiently, the ascensive force of the hot gases, and thus works by otherwise wasted energy. In other cases it is practicable to pass the gases through boilers before they go to the chimney, and thus to raise large amounts of steam. The gases are then cooled down so far that they enter the chimney too cold to furnish all the draft needed; in such cases a small fraction of the steam generated will run a steam engine or steam turbine, and run a fan capable of furnishing all the draft needed. In this manner considerable steam is available for other purposes, and great economy is effected.

CHIMNEY DRAFT.

The principles involved are not obscure or complicated. The total pull, or suction, which a chimney can produce, assuming it to be filled with hot air, is simply due to the ascensive force of the hot air inside, and the measure of this is the difference of weight of the chimney full of hot gases and what it would be if filled with cold air of the temperature outside.

Illustration: A chimney is 6 feet square inside and 100 feet high, uniform, with the gases inside at an average temperature of 500° F., and specific gravity (air = 1) of 1.06. The air outside is at 80° F. What is the ascensive force of the hot gas inside, in total pounds, in ounces per square inch and inches of water gauge?

The volume of the space in the chimney—chimney volume—is $100 \times 6 \times 6 = 3600$ cubic feet. This volume, filled with air at 32° F., would weigh

$$3600 \times 1.293 = 4654.8 \text{ oz. Av.} = 290.9 \text{ pounds.}$$

And, filled with gas at 500° F.,

$$290.9 \times 1.06 \times \frac{491}{500 - 32 + 491} = 157.9 \text{ pounds.}$$

If filled with outside air, at 80° F., the weight would be

$$290.9 \times \frac{491}{80 - 32 + 491} = 265.0 \text{ pounds.}$$

We, therefore, see that the hot gases in the chimney, weighing 157.9 pounds, displace 265.0 pounds of cold air, and the tendency of the former to rise upwards in this ocean of air must be

$$265.0 - 157.9 = 107.1 \text{ pounds.}$$

To put it in another way, if a piston fitted into the chimney at the bottom, and could move without friction, the piston would have to be loaded with 107.1 pounds to keep it from moving up the chimney. The total upward pull of the chimney is therefore 107.1 pounds.

Since this would be exerted on a piston $6 \times 6 = 36$ square feet in area, the pull or suction per square foot, in pounds, is $107.1 \div 36 = 2.98$ pounds, and in ounces per square inch

$$(2.98 \div 144) \times 16 = 0.331 \text{ ounce per square inch.}$$

If the pull or suction is measured on a gauge, as by water pressure, the pressure of a 1-foot column of water at ordi-

nary temperatures is 1000 ounces per square foot, or 1 inch of water is

$$(1000 \div 144) \div 12 = 0.597 \text{ ounces per square inch.}$$

The total pull of the chimney is therefore equivalent to

$$\frac{0.331}{0.579} = 0.57 \text{ inch of water gauge.}$$

By exactly similar methods of calculation the theoretical total suction of a chimney of any given height and temperature of gases inside and of air outside may be obtained. The suction expressed in ounces per square inch, or in water gauge is, of course, independent of the cross-sectional area of the chimney; it depends only on its height and on the temperatures inside and outside.

The above calculated total suction (allowing nothing for friction, etc.) is called the total head of the chimney, and is usually expressed in terms of cold air (at 0° C.) instead of in water. Cold air is a fluid, and water is 772 times as heavy as it; therefore, a gauge pressure or hydrostatic head of 0.57 inch of water is the same as

$$0.57 \times 772 = 440 \text{ inches of air.}$$
$$= 36.5 \text{ feet of air.}$$

What this head really represents is clearly seen from the above calculations. Its value is to be obtained directly from the height of the chimney, temperature inside and out and specific gravity of the chimney gases (air = 1) by the following relations, in which

h_o = total head in feet of air at 32° F.
h_o = total head in meters of air at 0° C.
t = temperature in the chimney, F°.
t = temperature in the chimney, C°.
t' = temperature of outside air, F°.
t' = temperature of outside air, C°.
D = Specific gravity of chimney gases, air = 1.
H = Height of chimney in feet.
H = Height of chimney in meters.

$$coef = \text{coefficient of gaseous expansion, F°} = \frac{1}{491}$$

$$\text{coef} = \text{Coefficient of gaseous expansion, C°} \frac{1}{273} = a$$

$$h_o = H \left[\frac{(1 - D) + coef\,[(t - 32) - D\,(t' - 32)]}{[1 + coef\,(t' - 32)]\,[1 + coef\,(t - 32)]} \right]$$

$$h_o = H \left[\frac{(1 - D + \text{coef}\,(t - D\,t')}{(1 + \alpha\,t')\,(1 + \alpha\,t)} \right]$$

The author is not fond of using formulas whenever their use can be avoided. The above formulas express in the simplest mathematical form the principles which have been so far explained and used in the calculations, but it is strongly urged that the formulas be kept "for exhibition purposes only," and that when any specific case is to be worked it be attacked from the standpoint of the principles involved, as explained in the case worked. In other words, if one understands properly and thoroughly the basic principles, he has no need of the formula; if one does not understand the principles, the formula had better be kept forever in "innocuous desuetude."

The total head, obtained as above, is the theoretical head. It is like the pressure on the piston of a locomotive—the total available force for all purposes. Just as the pressure on the locomotive piston is used up in friction in the engine and in moving the engine itself, and the residue is the *available* pull on the draw-bar which moves the train, so the total head of the chimney is partly used up in friction in the chimney itself, partly in giving velocity to the gases as they pass out of the chimney, and the residue is the *available* head which draws or pulls the gases through fire-grates, furnaces and flues up to the base of the chimney. If the chimney could be momentarily completely closed at the bottom, except for the gauge opening, and the air inside be brought to rest, the gauge would show the total head; as soon as dampers are opened connecting the flues, air moves up the chimney, and the gauge pressure is lessened by the head required to move the gases and that absorbed in their friction in the chimney.

Head Represented in Velocity of Issuing Gases.—This item always exists when the chimney is working, and depends only on the velocity of the gases as they escape and their temperature. The hydraulic head necessary to give any fluid a velocity V is simply the same as the height which a falling body must fall in order to acquire that same velocity; *i. e.:*

$$h = \frac{V^2}{2g}$$

in which expression, 2g is the constant acceleration of gravity, 19.6 meters or 64.3 feet, and the velocity is in meters or feet per second. If we know, therefore, the velocity of the gases issuing from the chimney, or can calculate or assume it, we can get h. In practice the velocity does not vary within very wide limits. In small house chimneys it may not exceed 3 feet per second, in boiler chimneys 6 to 12 feet per second, in furnace chimneys 12 to 20 feet per second. The temperatures of these issuing gases is, moreover

	C°	F°
In small chimneys.....	100 to 200	200 — 350
In boiler chimneys.....	100 to 300	200° — 550
In furnace chimneys....	300 to 1000	550° — 1800°

If the chimney in question has, therefore, a known velocity of exit of its gases, h can be calculated; but it must not be forgotten that h will be in terms of the kind of gases which is escaping; *i. e.*, of hot gas, and to subtract it from or compare it with h_o we must reduce it to its equivalent head in terms of cold gas. This is merely a matter of taking into account the specific gravities or relative densities of hot gas and cold air, which are inversely proportional to their absolute temperatures; that is, if D represents the relative density of air and chimney gases at the same temperature:

$$h_{o\,vel.} = h \times \frac{D}{1 + \alpha\,t} = \frac{V^2}{2g} \cdot \frac{D}{1 + \alpha\,t}$$

Illustration: Assuming the actual velocity of the gases issuing from a furnace chimney to be 15 feet per second, and their temperature 500° F., density 1.06 (air = 1), what will be the head represented by the velocity of these gases in terms of cold air at 32° F?

The head represented, *in terms of hot gases at 500° F.*, is

$$h = \frac{V^2}{2g} = \frac{15^2}{64.3} = 3.5 \text{ feet.}$$

In terms of air at 500° F. is

$$3.5 \times 1.06 = 3.71 \text{ feet.}$$

And in terms of air at 32° F.,

$$3.71 \times \frac{491}{500 - 32 + 491} = 1.9 \text{ feet.}$$

Out of the total head which this chimney produces (say 36.5 feet) 1.9 feet is represented by the velocity of the issuing gases, or 5.2 per cent of the whole, leaving 34.6 feet to represent loss by friction in the chimney and the available head. We will proceed to discuss the loss of head due to friction in the chimney.

Head Lost in Friction in the Chimney.—This varies with the smoothness or roughness of the walls, and has been determined experimentally for air moving with different velocities. The manner of expressing the friction loss is, to put it as a function of the head necessary to give the gases their actual velocity, assuming there were no friction. Thus, supposing as in the preceding paragraph, the actual velocity of the hot

gases is 15 feet per second, and the head (in terms of cold air) necessary to give that velocity, not considering friction, is 1.9 feet, then the head lost in friction in getting up this velocity will be

$$h_{\text{friction}} = 1.9 \times \frac{H}{d} K.$$

That is, it will be proportional to H, the height of the chimney, inversely as d, the diameter or side, if square, and to a coefficient K, determined by experiment. The latter varies, according to Grashof's experiments, between 0.05 for a smooth interior to 0.12 for a rough one, and averages 0.08.

Illustrations: Assuming the height of the chimney 100 feet, its section to be 6 feet square, the coefficient of friction K = 0.08, and the head represented by the net velocity of the hot gases in the chimney to be 1.9 feet of cold air, what is the head lost in friction in the chimney?

The ratio of height to side is $100 \div 6 = 16.67$, which multiplied by K gives 1.33 as the value of the function containing these three terms. This means that 1.33 times as much head has been lost in friction as is represented by the net actual velocity of the gases as they pass up the chimney. Therefore,

$$h_{\text{friction}} = 1.9 \times 1.33 = 2.5 \text{ feet cold air.}$$

Another way of looking at this, which is sometimes useful in considering the height of a chimney, is to say

$$h_{\text{friction}} = 0.025 \text{ H.}$$

Or, that in this case, the head lost in friction amounts numerically to one-fortieth the height of the chimney.

If we subtract the head lost in friction plus that represented in the net velocity of the gases, from the total gross head, the residue is that available for doing work external to the chimney. In the specific case of the preceding illustrations we have

h_o = total head	= 36.5 feet	=	100	per cent
h_{velocity} = velocity head	= 1.9 "	=	5	"
h_{friction} = friction in chimney	= 2.5 "	=	7	"
$h_{\text{available}}$ = available head	= 32.1 "	=	88	"

Available Head of a Chimney.—This is the part of the total head which remains after subtracting the head lost in friction in the chimney and that represented by the velocity of the issuing gases. In the specific cases considered in the above illustrations, the net available head amounted to 88 per cent of the whole theoreticial head. If we assume limiting conditions as found in practice, we can find the limiting values of this proportion. Calling the cases I and II, those with minimum and maximum absorption of head in the chimney itself, we have

	Case I.	*Case II.*
Temperature of issuing gases	100° C.	1000° C.
Velocity of issuing gases per second	1 meter	7 meters
Ratio H to d	10	50
Coefficient K	0.05	0.12
Specific gravity of gases (air = 1)	1.00	1.06
Head as velocity of gases (meters of air)	0.04 m.	0.56 m.
Head as velocity of gases (feet or air)	0.13	1.87
Head absorbed in friction (meters of air)	0.02	3.36
Head absorbed in friction (feet of air)	0.07	11.2
Head used up in chimney (meters)	0.06 to	3.92
Head used up in chimney (feet)	0.20 to	13.0
Water gauge pressure thus lost, m. m.	0.1 to	5.0
Water gauge pressure thus lost, inches	0.003 to	0.2

The available head will, therefore, be the theoretical total head minus a loss in the chimney itself, which may amount to a maximum of 3.9 meters or 13 feet, representing an absorption of water gauge pressure up to 5 millimeters, or 0.2 inch at a maximum. Under ordinary conditions half these quantities would be a rather high chimney loss.

In most conditions which confront the metallurgist, the question is to determine how high a chimney should be built in order to supply a certain available draft determined by practice to be necessary. For instance, to burn a certain amount of coal per hour on any grate requires a certain amount of draft. This amount is increased if the draft is increased, and *vice versa*. In boilers, 18 pounds of coal burned per square foot of grate surface per hour is highly economical practice, and requires a draft of 0.4 inch to 0.8 inch of water gauge, according to the kind of coal burned. In furnaces where the amount of coal burned is greater per hour there will be usually a correspondingly greater temperature in the chimney. To calculate the height of chimney required it is necessary to assume only the temperature in the chimney, the available draft required and an average chimney loss.

Problem 19.

It is desired to design a chimney for a puddling furnace, the grate of which is 4 feet by 6 feet, and which shall burn 30 pounds of bituminous coal per hour per square foot of grate surface. Temperature of gases entering the chimney 1200° C., at the top probably 1000° C. Specific gravity of gases 1.03 (air = 1). Draft required 0.6 inch of water gauge. Outside temperature 30° C.

Solution: We can assume that since the gases will be at an average temperature of 1100° C. in the chimney, their velocity will be high, and that at least 0.1 inch of water gauge pressure will be absorbed by the chimney itself. This makes a total requirement of 0.7 inches of water for total head, or

$$h_o = 0.7 \times 772 \div 12 = 45 \text{ feet of cold air.}$$

Or an unbalanced pressure or ascensive force of

$$45 \times 1.293 \div 16 = 3.64 \text{ pounds per square foot.}$$

Considering the air outside the chimney, its weight at 30° C. is equal, per cubic foot,

$$1.293 \times \frac{273}{303} \div 16 = 0.073 \text{ pounds.}$$

The gases inside the chimney weigh, per cubic foot,

$$1.293 \times 1.03 \times \frac{273}{1100 + 273} \div 16 = 0.0166 \text{ pounds.}$$

The height of the chimney being called H and its cross-section S, the volume is H × S, and the weight of hot air inside it is

$$(H \times S) \times 0.0166 \text{ pounds.}$$

And of an equal volume of cold air outside

$$(H \times S) \times 0.073 \text{ pounds,}$$

giving a total ascensive force of

$$(H \times S) \times 0.0564 \text{ pounds.}$$

But there is needed a total ascensive force of

$$S \times 3.64 \text{ pounds,}$$

in order to give the pull of 3.64 pounds per square foot, and, therefore, of necessity,

$$H \times S \times 0.0564 = S \times 3.64,$$

from which

$$H = \frac{3.64}{0.0564} = 64.5 \text{ feet.}$$

Concerning the cross-section of this chimney, it would not be safe to make it less in diameter than one-fiftieth of its height, because of lack of stability; in fact, one-twenty-fifth would be better practice. This consideration would make its internal diameter 2 ft. 7 inches, area 5.2 square feet. Another way of arriving at a diameter is to calculate the volume of the hot gases which must pass up the chimney, and assume for them some maximum velocity in the chimney, such as, let us say, 6 meters (20 feet) per second, and so get the minimum area necessary for filling this condition as follows:

Coal burnt per hour $4 \times 6 \times 30$ = 720 pounds.
Air theoretically necessary, assuming average bituminous coal (See Prob. 1) $= 123 \times 720$ = 88,560 cubic feet
Products of combustion at standard conditions $= 129 \times 720$ = 92,880 "
Volume chimney gases at 1100° C. $= 92{,}880 \times \frac{1700 + 273}{273}$ = 467,100 "
Volume per second = 130 "
Area of chimney, if maximum velocity is 20 feet per second = 6.5 square feet
Diameter, if round = 2 ft. 10 ins.

This chimney would do its work better, and there would be much less loss in friction, if the internal diameter were made 25 per cent greater than the above calculated minimum, say, therefore, 3 feet 6 inches, making the area nearly 50 per cent greater, and cutting down the velocity in the chimney to 13.5 feet per second.

Problem 20.

In the case of the puddling furnace of Problem 19, assume that the hot gases, instead of going directly into the chimney, are passed through the flues of a boiler placed above the furnace, and thence pass into the chimney at a point 15 feet higher than before. Assume chimney 3 feet 6 inches internal diameter, 64.5 feet high above the furnace flue, and that the gases now passing into it 15 feet higher up are at 350° C., and cool to 250° C. at the top of the chimney. The boiler flues introduce additional frictional resistance equal to 0.1 inch of water. The boiler raises steam at a net efficiency of 45 per cent, the steam engine utilizes the steam at a mechanical efficiency of 20 per cent, and a centrifugal fan supplies the forced draft needed at a mechanical efficiency of 25 per cent.

Required: (1) The total head of the chimney, when the furnace discharged directly into it, and the average temperature of the gases in it was 1100° C., and specific gravity 1.03 (air = 1).

(2) The head absorbed as velocity of the outgoing gases, their temperature being 1000° C.

(3) The head lost in friction in the chimney, in this case.

(4) The head which was available to run the puddling furnace.

(5) The total head of the chimney with the gases entering 15 feet above former flue, and average temperature 300° C.

(6) The head absorbed in this case as velocity of outgoing gases, their temperature being 250° C.

(7) The head lost in friction in the chimney in this case.

(8) The available head to draw gases into the chimney.

(9) The deficit of head which must be made up by forced blast under the grate of puddling furnace.

(10) The horse-power absorbed by the fan which furnishes this blast.

(11) The horse-power furnished by the engine using the steam from the boiler.

(12) The excess of power which is thus saved and available for other purposes.

Solution:

(1) Volume of gases in chimney,
$64.5 \times 3.5 \times 3.5 \times 0.7854 = 620.5$ cu. ft.
Weight at 32° F. (0° C.),
$620.5 \times (1.293 \div 16) \times 1.03 = 51.65$ lbs.
Weight if temperature is 1100° C.,
$51.65 \times \frac{273}{1100 + 273} = 10.27$ lbs.
Weight of equal volume of air outside at 30° C.,
$620.5 \times (1.293 \div 16) \times \frac{273}{30 + 273} = 45.18$ lbs.
Difference of weight = ascensive force,
$45.18 - 10.27 = 34.91$ lbs.
Ascensive force per square foot,
$34.91 \div 9.62 = 3.63$ lbs.
Total head in terms of cold air at 0° C.,
$3.63 \div (1.293 \div 16) = \mathbf{44.9}$ ft. (1)
In terms of water gauge pressure,
$44.9 \times 12 \div 772 = \mathbf{0.685}$ ins. (1)

(2) Volume of gases per hour at 0° C., (Prob. 19) = 92,800 cu. ft.
Volume at 1000° C.,
$= 92{,}880 \times \frac{1000 + 273}{273} = 433{,}100$ cu. ft.
Velocity per second,
$433{,}100 \div (3600) \div 9.62 = 12.50$ ft.
Head necessary to give this velocity, in terms of hot gases, at 1000° $= (12.50)^2 \div 64.3\ (2g) = 2.43$ ft.
In terms of gases at 0° C.,
$2.43 \times \frac{273}{1000 + 273} = 0.52$ ft.
In terms of air at 0° C.,
$0.52 \times 1.03 = \mathbf{0.55}$ ft. (2)
In terms of water gauge pressure,
$0.55 \times 12 \div 772 = \mathbf{0.008}$ in. (2)

(3) Assuming K, the coefficient of friction, 0.08, then
$$h_e \text{ friction} = \frac{V^2}{2g} \cdot \frac{273}{273 + t} \cdot \frac{H}{d} K \cdot D.$$
This is only an abbreviated form of the operations done under (2), adding the terms which account for the height, diameter and friction. Now, the velocity per second:
$$V = 92{,}880 \times \frac{1100 + 273}{273} \div 3600 \div 9.62 = 13.5 \text{ ft.}$$
Head necessary to give this velocity in terms of air at 0°,
$$(13.5)^2 \div 64.3 \times \frac{273}{273 + 1100} \times 1.03 = 0.58 \text{ ft.}$$
Proportion of this velocity head lost in friction $= \frac{H}{d} K = \frac{64.5}{3.5} \times 0.08 = 1.47$
Head lost in friction in chimney,
$0.58 \div 1.47 = \mathbf{0.85}$ ft. (3)
In terms of water gauge pressure,
$0.85 \times 12 \div 772 = \mathbf{0.013}$ in. (3)

(4)	*Cold Air.*	*Water Gauge.*
Total head	44.90 feet	0.685 inch
Absorbed in velocity of gases....	0.55 "	0.008 "
Absorbed in friction in chimney..	0.85 "	0.013 "
Available for the furnace.....	43.50 "	0.664 " (4)

(5) Volume of chimney gases,
$(64.5 - 15) \times 3.5 \times 3.5 \times 0.7854 = 475.7$ cu. ft.
Weight at 300° C., specific gravity 1.03 (air = 1),
$475.7 \times (1.293 \div 16) \times 1.03 \times \frac{273}{273 + 300} = 18.86$ lbs.
Weight of equal volume of outside air at 30° C.,
$475.7 \times (1.293 \div 16) \times \frac{273}{273 + 30} = 34.68$ lbs.
Ascensive force of air per square foot,
$(34.68 - 18.86) \div 9.62 = 1.64$ lbs.

Total head in terms of cold air,

$$1.64 \div (1.293 \div 16) = \mathbf{20.3}\text{ ft.} \qquad (5)$$

In terms of water gauge pressure,

$$20.3 \times 12 \div 772 = \mathbf{0.32}\text{ in.} \qquad (5)$$

(6) Velocity of issuing gases, per second, at 250° C.,

$$92{,}880 \times \frac{250 + 273}{273} \div 3{,}600 \div 9.62 = 5.14\text{ ft.}$$

Head as velocity in terms of cold air at 0° C.,

$$(5.14)^2 \div 64.3 \times \frac{273}{273 + 250} \times 1.03 = \mathbf{0.22}\text{ ft.}$$

In terms of water gauge pressure = **0.003** in.

(7) Average velocity of gases in chimney at 300° C.,

$$92{,}880 \div 3{,}600 \times \frac{300 + 273}{273} \div 9.62 = 5.63\text{ ft.}$$

Head lost in friction in terms of cold air,

$$(5.63)^2 \div 64.3 \times \frac{273}{300 + 273} \times 1.03 \times \frac{49.5}{3.5} \times 0.08 = \mathbf{0.27}\text{ ft.} \qquad (7)$$

In terms of water gauge pressure = **0.004** in. (7)

(8)

	Cold Air.	*Water Gauge.*	
Total head	20.30 feet	0.320 inch	
Absorbed in velocity of gases	0.22 "	0.003 "	
Absorbed in friction in chimney	0.27 "	0.004 "	
Available to draw gases in	**19.81** "	**0.313** "	(8)

(9)

Available head needed for puddling (4)	43.50 "	0.664 "	
Available head needed for boiler	6.43 "	0.100 "	
Total head needed for both	46.93 "	0.746 "	
Available head from chimney (8)	19.81 "	0.313 "	
Deficit, to be supplied by blast	**27.12** "	**0.451** "	(9)

(10) The 0.451 inches of water gauge equals

$$(0.451 \div 12) \times 62.5 = 2.35\text{ lbs. per sq. ft.}$$

The volume of air to be supplied is, at 30° C.,

$$88{,}560\text{ (Prob. 19)} \div 60 \times \frac{273 + 30}{273} = 1{,}638\text{ cu. ft. per min.}$$

Net work done by the fan,

$$1{,}638 \times 2.35 = 3{,}850\text{ ft. lbs. per min.}$$

Gross power needed by the fan,

$$3{,}850 \div 0.25\text{ (efficiency)} = 15{,}400\text{ ft. lbs. per min.}$$

Horse-power needed to drive the fan,

$$15{,}400 \div 33{,}000 = \mathbf{0.47}\text{ H. P.} \qquad (10)$$

(11) The boiler receives the gases at 1200° C., and discharges them at 350°, and 92,880 cubic feet of gases (measured at standard conditions) pass through per hour. The composition of these gases is not given, but from the specific gravity we might conclude that they contain on an average 10 per cent of carbon dioxide, since if they contained the maximum amount of that gas (about 20 per cent) their specific gravity would be 1.06 (air = 1). Assuming them, therefore, to contain

CO^2	10 per cent.
H^2O	10 "
CO, N^2, O^2	80 "

their heat capacity per degree per cubic foot would be, between 350° and 1200°.

		Oz. Cal.
CO^2	$0.1 \times [0.37 + 0.00022\ (350 + 1200)]$	= 0.0711
H^2O	$0.1 \times [0.34 + 0.00015\ (350 + 1200)]$	= 0.0573
CO, N^2, O^2	$0.9 \times [0.303 + 0.000027\ (350 + 1200)]$	= 0.0310
	Sum =	0.1594

Heat given up per cubic foot,

$$0.1594 \times (1200 - 350) = 125.5\text{ oz. cal.}$$

Heat given up by gases per hour to boiler,

$$92{,}880 \times 125.5 = 11{,}656{,}500\text{ oz. cal.}$$
$$= 728{,}500\text{ lb. cal.}$$

Heat in the steam produced per hour,

$$728{,}500 \times 0.45\text{ (efficiency)} = 327{,}800\text{ lb. cal.}$$

Heat equivalent of mechanical energy of steam engine per hour,

$$327{,}800 \times 0.20\text{ (efficiency)} = 65{,}560\text{ lb. cal.}$$

Heat equivalent of 1 hp-hour = 635 kg. cal.
= 1,400 lb. cal

Horse-power generated by the engine,

$$65{,}560 \div 1{,}400 = \mathbf{46.8}\text{ H. P.} \qquad (11)$$

(12) Net available power after supplying fan,

$$46.8 - 0.5 = \mathbf{46.3}\text{ H. P.} \qquad (12)$$

The Determination of Carbon in Ferrochrome and the Eimer Carbon Crucible.

BY C. OFFERHAUS, PH.D.

In the determination of the total content of carbon in iron and ferro-alloys we distinguish between direct and indirect methods. In the latter the carbon is first isolated by dissolving or evaporating iron, etc. In both kinds of methods we distinguish between dry and wet combustion.

The following notes refer to ferrochrome only. In view of the very low solubility, only the direct methods in the dry way and the indirect methods of evaporation are available in this case. In the latter methods the residue may be treated by dry or wet combustion.

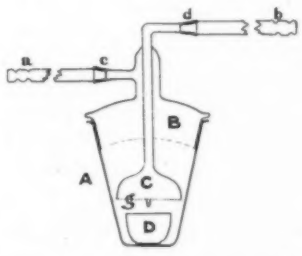


FIG. 1a.—CARBON COMBUSTION CRUCIBLE.

A—Platinum crucible.
B—Stopper.
a b—Glass tubes.
c d—Platinum or copper tubes.
C—Receptacle for copper oxide.
g—Perforated diaphragm.
D—Porcelain crucible.

While in this country and England the direct methods are used, the indirect chlorine method of Woehler is considered as the authoritative one in Germany. Thus Ledebur, in his well-known "Leitfaden für Eisenhutten-Laboratorien," mentions only the latter method for ferrochrome.

In view of the importance of the subject, I have compared some direct methods with each other and with Woehler's chlorine method. A short account of my determinations will be given in these notes.

INDIRECT METHODS.

Woehler's process consists in evaporating chromium, iron and silicon by means of a dry chlorine current with gradual increase of temperature up to dull-red heat. The residue consists of carbon and insoluble chromium trichloride. By means of a current of dry hydrogen, the latter is reduced totally or in part, and thus rendered soluble.

The total residue is then dissolved in cold water, and the carbon is separated by filtering. The carbon may then be oxidized, for instance, in a chromic acid solution, according to Sarnström.

This method requires considerable experience and the utmost accuracy. A great many operations have to be carried out and there are various sources of error.[1]

The chlorination was carried out in my experiments ex-

[1] Stahl und Eisen, 14, 359 (1894).

actly according to the instructions of Ledebur in his "Leitfaden für Eisenhütten-Laboratorien." The chlorine was produced, according to Graebe, from potassium permanganate and concentrated hydrochloric acid. Besides, a combustion tube with incandescent pieces of charcoal was employed in connection with this method.

The isolated carbon was oxidized either according to Sarnström in a chromic acid solution or, mixed with copper oxide, in an oxygen current. Both methods of combustion gave the same figures.

When the chlorination was carried out in such a way as to remove all the chloride of chromium by sublimation (so that reduction by a current of hydrogen was superfluous), the results remained unchanged.

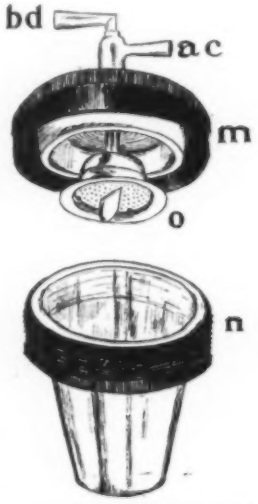


FIG. 1b.—DETAILS OF CRUCIBLE.

m, n—Couplings.
o—Receptacle for copper oxide.
b d and a c—The same as in Fig. 1a.

Direct Methods.

The principal conditions for a successful use of direct methods are a very finely powdered material and sufficiently high temperature. The ferrochrome was crushed and passed through a screen of 100 meshes per 1 inch, and was then ground for 1 hour in small quantities (1½ grams) in a mechanical agate mortar. The powder then no longer shows any metallic lustre.

One-half gram of this extremely fine metallic powder was mixed with 8 or 10 times as much fused and very finely ground lead chromate. The mixture was placed in a porcelain or copper boat, and was then introduced into a porcelain tube containing copper oxide. As combustion furnace, a Fletcher blast furnace was used, which gives a sufficiently high temperature. Combustion was carried out in a dry current of oxygen free from carbonic acid and free from hydrogen.

Although the combustion is in general completed in half an hour, the operation was not stopped before 1 hour, to be on the safe side. In all other details the combustion was carried out as usually.

It was found that the degree of fineness obtained with the treatment described above was sufficient. Another sample which was ground for 3 hours gave the same result. If lead oxide was substituted for lead chromate, the results remained unchanged.

Table 1 gives a summary of the results obtained by the two methods with one and the same sample of 70 per cent ferrochrome.

TABLE 1.

Woehler's Chlorine Method.

1 The chromium trichloride remaining with the carbon, was reduced and removed by solution in water and the residue was oxidized

	Per Cent C
(a) according to Sarnström	6.47
(b) mixed with copper oxide	6.39

2 All chromium trichloride was removed by sublimation. The carbon was freed from the adhering chlorine by washing with water and was oxidized

	Per Cent C.
(a) according to Sarnström	6.40
(b) mixed with copper oxide	6.47

Direct Methods.

1 The material ground for 1 hour in the mechanical mortar, gave

	Per Cent C.
(a) mixed with lead chromate	6.70
(b) mixed with lead oxide	6.72

2 The material ground for 3 hours, mixed with lead chromate, gave 6.79

Table 1 shows that with ferrochrome containing about 6.5 per cent C., the direct methods give 0.3 per cent more carbon. The direct methods also give higher values of C. than the indirect methods in steel and iron analysis (see for instance, R. Lorenz, *Zeit. f. Angewandte Chemie*, 1893, p. 313, 395, 411).

The direct methods are carried out more quickly than the indirect ones and ought to be considered as the more accurate ones, just for the reason that they give the higher figures. For this reason these methods are now recommended from competent authorities for iron and steel analysis (see *Transactions Amer. Inst. Mining Engineers*, 1905, p. 289).

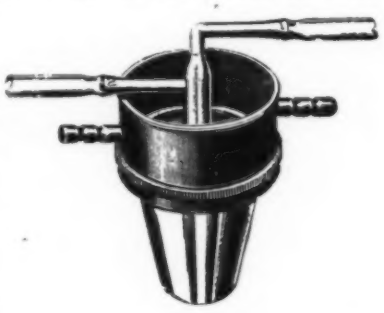


FIG. 2.—CRUCIBLE CLOSED WITH THE GLASS TUBES INSERTED AND WATER COOLER.

We have noticed above that a sufficiently high temperature is a main condition for direct dry combustion. If the porcelain tube is replaced by a platinum tube, it becomes easier to attain the necessary temperature. But the high temperature is required only at the point of combustion proper.

For this reason, the combustion furnace with porcelain or platinum tube was replaced by P. W. Shimer[2] by a platinum crucible with a copper stopper of special construction and by a brass tube with copper oxide.

The essential feature of this crucible is the water-cooled stopper for the protection of the rubber fittings and connections. Comparative determinations of the total carbon in pig iron and steel with this crucible applying an air current on one hand, and with a porcelain or platinum tube applying an oxygen current on the other hand, give a good agreement according to his statements.[3] He does not apply any correction for the flame gates diffusing through the platinum crucible.

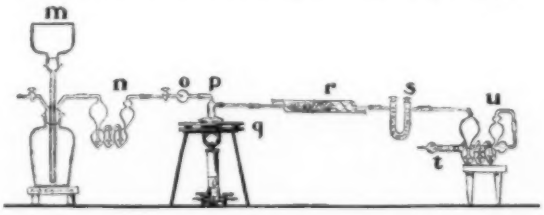


FIG. 3.—COMPLETE ABSORPTION TRAIN WITH CRUCIBLE AND BURNER IN PLACE.

m—Air or oxygen holder; n, washing bulbs; o, drop arrester; p, Eimer combustion crucible; g, asbestos pad; r, waterjacket head tube; s, drying tube; u, absorption bulbs; t, safeguard.

A. Eimer goes a step further. He places the copper oxide into the crucible and avoids rubber fittings and rubber connections by carefully grinding and fitting, respectively sealing, the platinum and glass connections.

Water-cooling and the copper-oxide tube thereby become superfluous.

The Eimer carbon combustion crucible is therefore a substitute for both combustion furnace and combustion tube; it

[2] Journal Amer. Chem. Society, 21; 557 and 23; 227.
[3] L. c.

combines in one apparatus the functions of the two, and has all advantages of the Shimer crucible to an increased degree.

Since a description of the Eimer crucible has not yet appeared in the chemical literature, it may be given here with reference to Fig. 1a. All other figures will be found self-explanatory.

The crucible *A* proper is distinguished from an ordinary

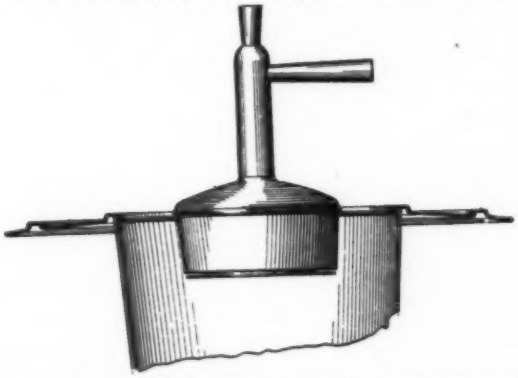


FIG. 4.—CRUCIBLE TOP TAKEN OUT AND USED WITH A PLATINUM DISC ON PLATINUM DISH FOR THE COMBUSTION OF LARGE QUANTITIES OF ORGANIC MATTER IN THE AGRICULTURAL LABORATORY.

platinum crucible by its conical form[4] and by its flat cut rim; it may replace at any time an ordinary platinum crucible.

The stopper *B* which may be made partly of copper, is carefully ground or coupled, so as to fit the crucible air-tight, and the same is the case with the glass tubes *a* and *b*, ground or fused into the platinum or copper tubes *c* and *d*.

The oxygen enters at *a*. It passes along the hot wall of the crucible and is thus preheated when it reaches the material to be oxidized.

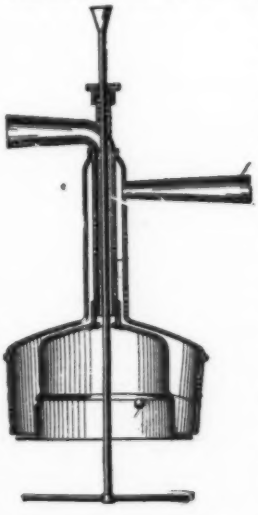


FIG. 5.—CRUCIBLE TOP PROVIDED WITH STIRRING ARRANGEMENT.

The gases of combustion pass out at *b*, after having passed the bell-shaped receptacle *C* placed near the bottom of the crucible and previously filled with sifted granular or wire-form copper oxide. To protect the upper parts, the crucible is set in a special perforated asbestos plate, about 5 inches square.

An essential advantage of the Eimer crucible is the absence of any organic substance, like rubber bands or rubber tubing. The rubber connections, and especially the rubber fittings of the Shimer crucible, cause a feeling of uneasiness. There exists always the danger that a small piece of the rubber, which by and by hardens, drops down when the top is placed on the crucible. The determination of total carbon in ferrochrome was carried out in the Eimer crucible as follows:[5]

0.2 gram of very finely powdered metal with 2 grams of fused and very finely ground lead chromate were mixed in a small porcelain crucible with thin walls, and this was then placed into the platinum crucible. Combustion was carried out in a current of dry oxygen, free from hydrogen and carbonic acid. A blast lamp was used, and has been proved necessary.

Although in this case the combustion is generally complete in half an hour, the operation was carried out for a full hour. The arrangement of the absorption train of the apparatus was the usual one.

A correction was made for the flame gases diffusing through the platinum into the crucible. This correction was found by special experiments, carried out under exactly alike conditions, to amount to 0.0058 gram CO_2 per hour.[6] This is the average of a number of determinations giving very nearly the same result.

The good agreement of the results of combustions in the Eimer crucible, while applying this correction, with those in the porcelain tube, render it improbable that this correction might be considerably compensated by the carbonic acid diffusing from the inside of the crucible to the outside.

The sample of 70 per cent ferrochrome mentioned above, which gave in the porcelain tube an average of 6.74 per cent C., showed, when determined in the Eimer crucible with the application of the above correction, an amount of 6.78 per cent C.

With another sample of 70 per cent ferrochrome, the determination in the Eimer crucible gave 6.10 per cent C.,[7] while Messrs. Booth, Garret and Blair found 6.11 per cent in the same sample.[8]

My conclusion is that for the analysis of ferrochrome, the chlorine method of Woehler is not to be recommended, since it gives too low values for C. Therefore, the direct method is preferable, and the Eimer crucible may be used here to good advantage.

HOLCOMB'S ROCK, VA.

[4] The conical form permits the introduction of Gooch crucibles.
[5] See Blair, The Chemical Analysis of Iron, 5th edition.
[6] A gasoline gas burner was used.
[7] This determination was made by Mr. J. H. Webb.
[8] According to a private communication from the chemical laboratory of Messrs. Booth, Garret and Blair, the procedure was as follows: One gram of finely ground material, intimately mixed with 2 grams of finely ground electrolytic iron, was burned at a high temperature in a platinum boat on a bed of alumina, placed in a platinum tube in a current of oxygen.

Bosses and Individualism in the Development of Chemistry.

Prof. Wilhelm Ostwald recently presented in Boston a suggestive address on the development of chemistry in France, England, Germany and the United States.

Prof. Ostwald pointed out that chemistry had its earliest developments in France. Owing to the centralizing methods of Napoleon I., science in France has always been imperialistic in its tendencies. There has always been a central leader in Paris, who played the rôle of "king" in chemistry. The succession was Lavoisier, Fourcrois, Berthollet, Gay-Lussac, Dumas, Wurtz and Berthelot, the present ruler, with Moissan already elected the next "king." The result has been to greatly retard the advance of the science.

The opposite conditions have existed in England, where individualism has been the rule. Boyle, Priestley, Cavendish, Davy, Faraday and others were not connected with the government, and had no encouragement or support from it.

In Germany, which consisted of thirty-six separate different countries during the development of chemistry, there has been a large number of centers of science and independent thinkers. At first Germany was far behind France and England. Liebig was the one who brought about the change. At present nearly three-fourths of the chemical investigation of the world is carried on in Germany, all of which is attributed to Liebig's methods.

In America, Prof Ostwald said the development of chemistry has been dependent on the development in foreign countries, and foreign methods have been introduced. At present, progress is rapid and the signs are hopeful, but the connection between theoretical and applied chemistry is not so well developed as in Germany, where at Ludwigshafen, for instance, there are 150 university graduates employed in technical work in one establishment, and the university professors and scientists in works are in close touch.

Earth Alkali and Allied Peroxides.

In our Vol. III., pp. 255 and 376, we have already dealt with the new series of peroxides which have been placed on the market last year by Roessler & Hasslacher Chemical Co. A special phase of the subject was dealt with in a recent paper by Dr. Richard von Foregger and Mr. Herbert Philipp presented before the New York Section of the Society of Chemical Industry on Jan. 19. The paper dealt with the properties and applications of the following earth alkali and allied peroxides, namely, the peroxides of calcium, strontium, magnesium and zinc.

As oxidizers, they come next to ozone, since after they have liberated their available oxygen, either a colorless solid residue is left which can be easily saturated from the oxidized medium, or a soluble salt—both of a harmless nature.

The constitution of the peroxides is explained by assuming a tetravalent O, thus:

$$R^{II} = O^{IV} = O^{II}$$

The O^{IV} is represented as being slightly wedged in between the R^{II} and O^{II} of the ordinary oxide, ready to escape as the opportunity is provided, thus explaining the action of the available O.

Calcium peroxide as a commercial product is the dehydrated product containing 60 per cent CaO_2 with 13.5 per cent available oxygen, but one containing 80 per cent CaO_2 with 17.8 per cent available oxygen has also been obtained. The specific gravity varies; that of the 60 per cent product is 0.603 and that of the 80 per cent product is 0.74. All the peroxides are practically insoluble in water, but they slowly dissociate, which is thus explained: CaO_2, $2H_2O$ is first formed as a solid, which goes into solution as $Ca(OH)_2$, H_2O_2 and this gives off its H_2O_2, these reactions being reversible according to whether the temperature is high or low.

A comparison of calcium permanganate with Ca peroxide is made, concluding a discussion which was brought up at the Bethlehem meeting of the American Electrochemical Society (see Electrochemical and Metallurgical Industry, 1905, Vol. III., p. 377). The permanganate $CaMnO_4 + 5$ aq. gives 13.2 per cent O in alkaline solution and 21.7 per cent O in acid solution against 13.5 per cent of 60 per cent CaO_2. Ca permanganate is, however, of a deliquescent nature, and dangerous on account of its unstability. CaO_2, like the other peroxides of the series, is comparatively stable in dry atmospheres, and can be heated up to 150° C. and 170° C. without any decomposition taking place. The fact that calcium permanganate decomposes so very easily in the presence of organic substances and that it is hygroscopic, places a barrier to its industrial success, though it could be manufactured very cheaply as a by-product of Weldon slimes. It has only been used for purifying water.

Interesting about strontium peroxide is the dissociability of its O in water, nearly 15 per cent of its available O was titrated in solution at 20° C. Much of what applies to these also applies to magnesium and zinc peroxides.

Calcium peroxide seems destined to be largely used for industrial purposes, on account of its large quantity of available O; magnesium, strontium and zinc peroxides are chiefly of medical interest on account of their non-toxic, non-irritant, physiological and chemical reactions.

The authors described a method by which they have been able to bleach cotton oil in 10 minutes. With the use of calcium peroxide as bleaching agent, there is no danger whatever in handling this peroxide, nor does any saponification take place. With a 60 per cent calcium peroxide the operation is as follows: Add, while stirring the oil, about 1-10 to ⅓ per cent in weight of powdered peroxide. Following this, slowly add 1-6 to 1-5 per cent of sulphuric acid, 66° Be. The reaction is visible; the oil which otherwise would turn black by the addition of sulphuric acid, becomes light at once; when the addition of acid is finished, the bleach is also finished, so that the whole process only lasts about 10 minutes. Filtration can then take place right away. The economy of the process depends greatly on the finely powdered state of the calcium peroxide.

Since oxygen is the most logical disinfectant, and since the germicidal power of active oxygen has been established, the question suggests itself whether some of these non-toxic peroxides are not very useful means with which to sterilize and preserve. The assumption is justified by the harmlessness which is a property of these products. Calcium and magnesium are no foreign substances to water, milk, beer or any food substance, consequently their introduction in the form of peroxides cannot be harmful to our system.

The authors gave a preliminary report on a method of using peroxides as sterilizers. One experiment which they described was interesting. It related to the prevention of sweet cider from fermenting. Raw apple juice treated with calcium peroxide can be made to ferment at an earlier date when in contact with air than it would under ordinary circumstances, and the increased amount of peroxide apparently only accelerates the fermentation.

On the other hand, 350 cc. raw juice as it came from the press was treated with a mixture of 0.1 gr. calcium peroxide of 60 per cent CaO_2 and 0.2 gr. magnesium peroxide of only 15 per cent MgO_2. The liquid was kept in a bottle which was hermetically sealed immediately after the addition of the peroxides, and shaken sufficiently to sterilize the bottle. The first effect is a brownish coloration of the cider, which, however, begins to fade after two weeks, and after another couple of weeks the impurities begin to settle and the original color, but somewhat brighter, is restored. No fermentation as yet, after nearly four months, has taken place. The authors gave a tentative explanation of these facts.

Magnesium peroxide was mentioned by the authors as the ideal means for sterilizing drinking water—not on a large scale, but for the use of the soldier in the field, the workman in tropical countries and, sometimes, the citizen in regions where the water is known to be typhoid contaminated. For this purpose the authors proposed simple tablets, similar, for instance, to effervescent lithia tablets, but in the present case being effervescent magnesium tablets, consisting of magnesium peroxide and citric acid.

Finally, the authors suggested the sterilization of milk by small quantities of calcium peroxide.

Notes on Electrochemistry and Metallurgy in Great Britain

(From Our Special Correspondent.)

Presidential Addresses and Electrochemistry.

In my first letter of this series, written nearly a year ago, I chronicled the items of chief interest to electrochemists in the various presidential addresses delivered at the opening of last winter's sessions of the various scientific institutions. Of this year's addresses, Mr. John Gavey, the new president of the Institution of Electrical Engineers, confined his address to his special sphere of telegraphy and telephony, and did not, therefore, touch upon electrochemical or electrometallurgical processes. Passing reference to electrothermal processes of iron and steel production was, however, made by Mr. L. S. Pearce in his inaugural address as chairman of the Manchester Local Section of the Institution of Electrical Engineers, who followed orthodox views in his presentation of the case, as may be instanced from the following quotation: "The manufacture of pig iron in the electric furnace is of little interest to electrical engineers in this country, as with the cheap supply of fuel available here no electric furnace can compete with a modern blast furnace. It is not improbable that the electrical energy required for the electric furnaces will be ob-

tained from gas engines operated by gases from the blast furnaces. Probably only two of the modern electric furnaces are capable of adoption for English steel smelting, but it has been proved that either of these processes can compete successfully with the Sheffield crucible furnace with electrical energy at anything like a reasonable figure."

Dr. W. M. Thornton's inaugural address to the Newcastle Local Section of the Institution of Electrical Engineers, while in no way electrochemical in its title, is of such striking interest in two of its sections that a reference to them will not be inappropriate. Dealing in the first instance with the value of research as an investment, Dr. Thornton said: "There is speculative search into the unknown on lines suggested by unique chains of thought, arising from new observations or strong co-ordinated thinking. Work of this kind cannot be undertaken to order. There are times of inventive activity in which ideas come rapidly. Then follows the patient experimental search for truth where so many fall out. Now, if it is to come at all, a time of speculative activity, almost inevitable, follows the completion of a university course, and, it may be, the taking of a degree. It is then encouragement and, perhaps, pecuniary help that are of vital importance to a young student. He should have the opportunity of seeing how to carry out ideas by watching or helping in the research work of his professor, and the advantage is mutual. The enthusiasm of a pupil is the most refreshing thing that can come into the life of a teacher, and the friendship or sympathy of the elder man is always greatly prized by the younger. After all, in the light of the immense unknown, the difference between teacher and taught is very small. It is only the case of one student a little in advance helping another along the same road."

Dr. Thornton also appealed to manufacturers to give a freer hand to young engineers, and suggested that those of ability and promise should be drafted into the confidential department, design or test rooms, and set to work on new things. "They say no man becomes a good glass-blower until he has broken 10 pounds of glass in the process of learning. There should also be some similar allowance made for crude ideas in engineering, say £10 sterling. Fuses cover a multitude of sins in the test room, and it would take a good deal to reach this limit. One result of college training is to produce a large crop of ideas, more or less crude, out of which the finished articles may emerge."

As regards the relation of research and practice, a case was instanced of what I may perhaps call "the suggestiveness of parallelism." Some years ago in carrying out some bacteriological experiments, Dr. Thornton noticed, as others had done previously, that alternating currents caused bacteria to place themselves parallel to the lines of flow. Differing from other investigators, Dr. Thornton sought parallels in other fields, and found that the movement depended entirely upon the relative conductivity of the organism and of the surrounding liquid, so that the former behaves as a rod of iron in a magnetic field. Wishing subsequently to design an apparatus to indicate the state of charge on electric cables, to see whether they were safe to handle or not, Dr. Thornton describes his chain of thought in the following terms: "The simple electroscope was first thought of, but rejected as not mechanically strong enough to be placed in a plate-layer's hands. It then occurred that one might use the same thing on a small scale, observing the movement in a kind of linen tester's microscope. On trying this I noticed a small spark pass between two particles of carbon suspended in oil, and the idea at once came, why not look for the sparks? In 10 minutes or so after this the first 'voltascope' was made, and tried on a 2,000-volt circuit, and a little while later on 20,000 volts. The instrument, as it is now made, consists of a glass tube containing oil and short, fine carbon rods. Contact is made across the mains through a heavily-insulated wire, having an ebonite of fiber handle with sharp steel points to get good contact. It works equally well with direct and alternating currents, and in any position. As soon as contact is made the carbon filaments become polarized and form an irregular chain, along which a small current passes, jumping across minute gaps between the particles, and so forming sparks which are instantly extinguished by the oil, their constant appearance and extinction giving the tube the effect of scintillation."

All this is exceedingly interesting to all concerned with scientific research, and not least to electrochemists and electrometallurgists. It specially serves to emphasize the value of an alert intelligence, broad sympathies, and a high standard of general scientific knowledge to the man who would, in any branch of technology, serve his day and generation both faithfully and usefully.

Mr. Swinburne, in an address to the students of the Manchester Local Section of the Institution of Electrical Engineers, chose as his subject "Efficiencies." The importance of looking at things from a monetary point of view was urged, because "all engineering is a question of money." Money matters on the engineering side are not generally regarded in the manner set out by Mr. Swinburne in the following words: "In making any bargains with Nature we always lose in a sense, and we are so accustomed to it that we take it quite contentedly, and merely try to lose as little as possible in the transaction. As I said before, the relation of what we do not lose to the whole is termed 'efficiency.' In dealing with our fellow men we always hope to make a profit, and we sometimes do. In such a case it might be correct to talk of an efficiency of over 100 per cent, but it would be unusual. It might be still more unusual to say a bankruptcy which resulted in a payment of 6s. 8d. in the pound was a transaction with an efficiency of 33⅓ per cent. But there would be enough justification for such a proceeding to enable me to discuss some aspects, even of electrical commerce, under the head of 'efficiency.'"

Passing to thermo-dynamic questions, Mr. Swinburne was also heterodox. He said: "Heat includes what is called sensible heat, or heat that makes things hot; latent heat, such as the heat that disappears when ice is melted or water vaporized at constant temperature and chemical energy. * * * It is not orthodox to call chemical energy heat; and you will not find any such treatment of the subject in books on thermo-dynamics. At present I believe I am alone in classing chemical energy or defining heat so as to include chemical energy, but the treatment of chemical energy in chemical thermo-dynamics is quite consistent with my definition, so I may use it, provided I give you due warning of any heterodoxy. I think that it is not realized that chemical energy is necessarily low-grade enrgy, only partially convertible into work. This involves the idea of chemical temperature, which may be important in chemistry in discussing the way any given possible reaction will go; but we are not concerned with that here. It will be said that the coal is cold when it is put into the furnace, as cold as the air in fact; so that if this idea is right none of the chemical energy is available. But I must give some idea of what I mean by chemical temperature. If carbon and oxygen are heated to a high enough temperature you get a state on which, in the least fall of temperature, the carbon and oxygen combine and give out sensible heat of that temperature, under the other circumstances that obtain. The least increase of temperature, however, causes the carbon and oxygen to separate again, absorbing sensible heat. At this temperature, therefore, under the pressure and quantitative relations of the carbon, oxygen and carbon monoxide, sensible heat and chemical energy are interchangeable. This temperature may be called the chemical temperature of the energy of carbon and oxygen."

The bulk of the paper was, however, given to a disquisition on municipal trading, but this is too remote and insular a subject for discussion in my letters.

Of direct importance to electrochemists was Prof. Threlfall's

address to the Birmingham Local Section of the Institution of Electrical Engineers, which was entitled "On Some Problems in Electro and Electrothermal Chemistry." Prof. Threlfall's repute as an exponent of general thermo-dynamics is exceedingly high, and his recent Institution paper on the testing of the losses in alternating-current generators by air calorimetry was ingenious and convincing, although too complicated for the commercial testing of a manufacturing firm.

As first in intrinsic importance the atmospheric fixation of nitrogen was discussed. The speaker, after dealing with the commercial prospects (whose foundation he considered to be electrical power at $10 per electrical horsepower-year), proceeded to make certain suggestions, such as whether mercury-vapor air and steam at, say, 160° C., could be made to yield ammonia, if not oxide of nitrogen, a process which would be impracticable if the mercury were not recoverable. For the future, Prof. Threlfall looked forward to a time when the price of fixed nitrogen should have dropped to one-tenth of its present value.

The next subject treated was that of non-conducting carbons, in regard to which a striking parallel was pointed out as existing between aged monoclinic sulphur and graphite crystals of diamond shape, and van't Hoff's pressure-temperature diagram was applied to the manufacture of diamonds. From this it was deduced that considerably higher pressures than had yet been applied would be necessary to produce large diamond crystals. Emphasis was laid upon the interest in the transformations to which boron, silicon and selenium were subject, Prof. Threlfall's view being that "the most interesting phenomena may be expected to occur only after the pressure is high enough to produce a material change of volume in the compressed substance."

The Institution of Mining and Metallurgy.

At the ordinary meeting in November the papers discussed were those crowded out by the length of the virile discussion in October, on Mr. Dietzsch's paper. I am now able to deal with these and the discussion which they occasioned. The first, on "The Occurrence of Gold in Upper Sarawak," by Mr. J. S. Goekie, was mainly a geologist's paper, and save for incursions into the idiosyncrasies of Chinese laborers, the discussion was of the same order. "The Computation of Assay Values" formed the subject of the second paper, by Mr. W. Crossley, in which several methods of computation were discussed and contrasted. The paper applies chiefly to banket reefs of varying width and values. The paper and resultant discussion do not admit of being easily abstracted; they would form good copy for a mining magazine, but are foreign to the scope of my letters, which have to treat generally with the problems of electrochemical and metallurgical processes of treatment. Mr. Crossley also described in the third paper "A Graphic Calculator." The fourth paper was by Mr. E. J. Way, on the "Ore Valuation of a Witwatersrand Mine," and was similar in matter to the second paper.

At the ordinary meeting in December three papers on gold mining were submitted. One, by A. R. Weigall, dealt with "Gold Mining in Japan," the other two, respectively by Mr. W. Hamilton and Mr. T. C. Scrutton, dealt with the occurrence and treatment of gold in Sarawak.

The 1906 Meetings of the Iron and Steel Institute.

The Council of the Iron and Steel Institute have arranged that the annual general meeting of the Institute shall be held in London on May 10 and 11, 1906. In place of the usual Autumn meeting, a joint meeting with the American Institute of Mining Engineers will be held in London on July 23 to 28. It is intended during the week following to give the American visitors an opportunity of seeing some of the iron-making districts. It is anticipated that the visiting party will include many of the leading ironmasters who entertained the Iron and Steel Institute in America in 1890 and 1904. The Lord Mayor of London has kindly consented to act as chairman of the London reception committee, and to give an evening reception at the Mansion House.

The Faraday Society Meeting.

The December meeting of the Society, held on the 12th of the month, was well attended. Lord Kelvin was unavoidably absent, and we therefore had the pleasure of Mr. Swinburne as chairman, and at the same time as the reader of the first paper ("The Physics of Ore Flotation," by Mr. Swinburne and Dr. Rudorf). Carrying the conscience of the chair with him to the blackboard, Mr. Swinburne ruthlessly closured himself at the end of 20 minutes to make way for the next paper, by Prof. Huntington, on the "Concentration of Metalliferous Sulphides by Flotation."

I understand that the genesis of the two papers,* which were discussed simultaneously, was a battle royal at the Royal Courts of Justice, where Mr. Swinburne and Prof Huntington appeared on opposing sides as expert witnesses. The second round was so interesting that one regrets missing the first.

The discussion was opened by Mr. Bertram Blount, who confessed his ignorance of the subject, despite the fact that he had worked at the problem. He had listened to both papers, and remained entirely unconvinced. He could not subscribe to either hypothesis, and he had not one of his own ready to offer in substitution. As far as he saw, it was necessary to have, firstly, an appropriate gas; secondly, an appropriate solid; and, thirdly, an appropriate temperature of application. What was important was the practical effect that valuable metalliferous particles could be separated from valueless gangue. Experiment was their only guide, and they always had to fall back upon laboratory trials in order to get the conditions under which the valuable and worthless parts could be separated.

Mr. J. G. A. Rhodin, in a fluent and excellent speech, explained that he shared Mr. Blount's difficulties. The question was: how did the gas get there, and how did it get in contact? When an envelope of gas surrounded a solid, the stress was equal all round. When carbon dioxide gases impinged on a solid, a considerable dynamic effect was evidenced. The impact, however, was much greater than could be exercised by carbon dioxide in motion. To account for the dynamic effect they had two theories: one of impact, and a second (and more feasible) one that carbonic acid gas was evolved in close proximity with all the solids in the liquid. The case of calcium carbonate in sulphuric acid was a distinct case of mass action, which Gulberg and Waage's law explained. He believed that in the case of ore flotation part of the solid went into solution as solid. The solubility of calcium carbonate was very low, but the continued evolution of CO_2 would make this a typical case of mass action. Ferric carbonate and manganese carbonate were more soluble, and were simply in a transition stage. Then if gaseous CO_2 was evolved in the solution, the gas would get to the surface, carrying with it the particles of ore and gangue. On these submerged particles occluded gases were actually present, and to get rid of these was well-nigh impossible. He did not believe that Prof. Huntington's attempts to remove these films of occluded gases could possibly have been successful. Finally, he did not understand how a liquid could surround a solid without a layer of air between the liquid and the solid, unless they fell back on the ether as an explanation, which was always their last leg scientifically, when all other explanations failed. It seemed to him that all Messrs. Swinburne and Huntington between them had succeeded in doing was to explain Quincke's formula.

Dr. Steinhart, who followed Mr. Rhodin, began by remarking that there was a third class of flotation, *i. e.*, that of the Zinc Corporation, Ltd., which was the outcome of the first battle of the two theories. Dr. Steinhart then asked a general

* A summary of both papers will be found in an article on another page, under the title "Ore Dressing by Flotation."—Ed.

question concerning the Elmore method of flotation: did not this take place in a vacuum?

Prof. Huntington, intervening, remarked that Elmore used both acid and oil.

Dr. Steinhart's next query was as to whether the original idea had not been that of separating galena from zinc blende, Mr. Swinburne replying in the affirmative, but that it had been found impossible, the process acting as agangue carrier only.

Mr. F. S. Spiers mentioned the persistence of films of air, and stated that he had experimentally tried the Volta contact effect with plates of aluminium and platinum in the best vacuum attainable. In spite of heating to a certain point, no diminution of contact effect occurred, but above this point the formation of a film of surface oxide on the aluminium reduced the voltage effect to zero. He, therefore, disagreed with Dr. Huntington's claim that the air film had been removed, and stated that his (Mr. Spiers') conviction was that gaseous films were impossible of removal.

Dr. Perkin next deprecated the confusion which seemed prevalent between occlusion and air films, and Mr. Bluman asked why, granted that there was occlusion, the films chose the sulphide and not the gangue.

What was nominally the reply to the discussion, but owing to the interjection of remarks was actually the opening of a further discussion, was then commenced by Prof. Huntington, who remarked that the question of an air film was very different from that of an occluded gas, and that it was doubtful whether one got occluded gas with a sulphide. He could not see what was the necessity for a film. Given a sufficient angle of contact, a sufficient quantity of gas would adhere. He could not accept Mr. Rhodin's views as to the necessity of a film. A member then suggested that the separation of the gangue and sulphide particles was electrical.

Dr. Rudorf opened his part of the reply by asking Prof. Huntington whether if a particle floats or not depends on the contact angle, did not the contact angle depend on the air film? The authors did not lay entire stress on weathering; for instance, molybdenum sulphide was unaffected by weathering but flotation occurred.

After several more or less relevant remarks, Mr. Swinburne pointed out that the question of the air film was a side issue. Surface tension was affected by adhesion and by temperature. Metallic sulphides had less adhesion than gangue. Personally, he did not believe in an electrical theory, as the substances which floated best did not conduct. Mr. Swinburne and Prof. Huntington then reciprocally moved a vote of thanks to each other.

Dr. Walker's paper on "The Ions of Pure Water" being taken as read, Dr. Lowry, speaking on behalf of Mr. W. R. Bousfield and himself, expressed his virtual agreement with Dr. Walker. So far as he was concerned in his prior remarks on the subject, he had taken figures from Kohlrausch's work in 1884. A vote of thanks to Dr. Walker, moved by Mr. Swinburne, brought an interesting meeting to a close.

MARKET QUOTATIONS DURING DECEMBER.

Comparing the first and last days of December, there are very few changes to report in regard to the prices ruling in the chemical trade. Ammonia sulphate is about 5s. per ton dearer. Cyanides are dearer, the price of 8½d. per pound being reported on the 22d. Shellac also has risen to 190s. per cwt.

Passing to the metal markets, English lead fetched £17.16.3, a rise of £1.14 per ton during the month, and all the lead derivatives are correspondingly higher. The demand for copper is firm, stores of refined copper scarce, while large deliveries are not anticipated for a little while. Copper reached £79.15 per ton on Dec. 30. The rise during the year is over £11. Although a further rise is possible, the price of £100 per ton mentioned in some quarters is quite improbable. Straits tin closed at £165 per ton, after having touched £167. The general advance from £133 on Jan. 1 last is really phenomenal. Hematite pig iron closed at 71s. 6d., an increase of 1s. 6d. during the month, while Cleveland warrants closed at 54s., a similar advance of 1s. 6d. per ton marking the change of the month.

The general outlook seems to be exceedingly favorable, and Mr. Hadfield's prophecy in May last of a coming trade revival, if not a boom, was well founded.

LONDON, Jan. 3, 1906.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

ELECTRIC FURNACES.

Production of Chlorides of Carbon.—F. J. Mechalske, 808,100, Dec. 26, 1905. Application filed June 1, 1905.

Calcium oxide, calcium chloride and carbon (in the form of broken coke) are mixed and heated in an electric furnace to form oxychloride of carbon according to the reaction

$$2CaO + 2CaCl_2 + 10C = 4Ca\ C_2 + 2COCl_2$$

The oxychloride of carbon is passed through a mass of boneblack, coke or pumice, which results in its decomposition into carbon tetrachloride and carbon dioxide, according to the equation

$$2COCl_2 = CCl_4 + CO_2$$

Both of these products being in gaseous form are separated by passing the same through a reflux condenser, whereby the carbon tetrachloride is converted into liquid form, while the carbon dioxide is withdrawn by a compressor and liquefied. It is stated that sodium or magnesium chloride may be used as starting material instead of calcium chloride.

Metallurgical Furnace.—G. H. Benjamin, 808,187, Dec. 26, 1905. Application filed April 27, 1903.

The furnace contains four essential chambers: the calcining chamber, the reducing chamber, the electric combining chamber, the receiving or oxidizing chambers. These chambers are connected together. The ore is passed by a reciprocating rake through the calcining chamber, and is then subjected in the reducing chamber to the action of hydrocarbon flames. In the electric chamber there is a series of electric arcs through which the ore passes, and before and while the ore is subjected to the action of the arcs, finely divided and preheated, other materials, fluxes, carbon, etc., are mixed with the ore. "The current transmitted between the electrodes serves not only to form the arcs, thereby creating high-temperature effects, but also to produce electrolytic effects; *i. e.*, the separation or tearing apart of the materials where the materials acted upon form, so to speak, an 'electrolyte.' Such electrolyte may be formed from lime, carbon, or the various gases evolved from the decomposition of the ore body or the chemical reactions taking place between the ore body and the introduced body, and, further, the electric fields created between the electrodes act mechanically, especially where an alternating or pulsating current is used to agitate the falling metal and hold it suspended for an appreciable time in the arcs."

Manufacture of Calcium Carbide.—E. F. Price, G. E. Cox, J. G. Marshall, 809,842, Jan. 9, 1906. Application filed Oct. 19, 1904.

Ordinary carbon electrodes have generally been used up to the present in calcium carbide manufacture, instead of graphite electrodes, on account of the higher cost, the oxidizability

and the high heat conductivity of the latter. On the other hand, graphite has the important advantages of high electric conductivity, uniform composition and ease of machining. The object of the patent is to use graphite rods under such conditions as to not materially increase the cost, while the life is so greatly lengthened that the final cost is reduced to a minimum. The greater cost of the graphite is offset by the reduction in the cross-section and in the length of the electrode rods. The rods may be coated with tar and enclosed in iron

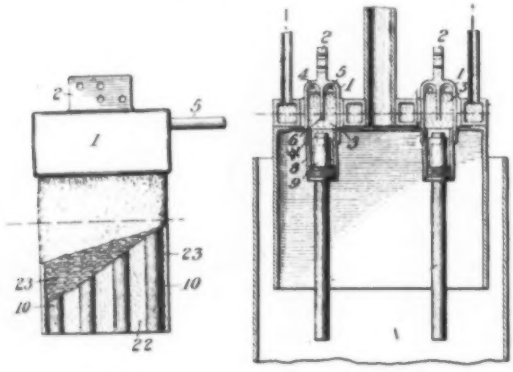


FIG. 1.—ELECTRODES FOR CARBIDE FURNACE.

sheaths, so as to exclude air from their surface. They are efficiently strengthened and protected from oxidation by the reinforcing body of cement 22 (Fig. 1), while a support 23 of thin foraminous metal, such as "expanded iron," is wrapped around the rods and plastered over with the cement. The electrode holder consists of a head 1 of cast iron with the terminal 2; within the holder is a water-chamber 3, with supply and discharge pipes 45. A longitudinal depending baffle 6 extends from the top nearly to the bottom of the water-chamber. The upper end of each graphite electrode rod 10 is threaded and screwed into a socket 9, making good electrical contact with it. The water-cooled holders and electrode sockets prevent the metal parts from burning out, and the long socket nipples 8 decrease the stub waste of the electrodes.

Electrolytic Processes.

Treating Molten Matte.—W .E. Koch, 808,849, Jan. 2, 1906. Application filed Feb. 19, 1903.

The object is to treat matte containing a mixture of different metallic sulphides, so as to remove the sulphur and at least partially separate the metals. This is done by electrolysis with simultaneously forcing a gas through the matte. As an example, the treatment of copper matte containing iron is described. The matte is tapped from the smelting furnace into a fore-hearth, where it settles to the bottom and is then tapped into an inclined trough 5. The upper diagram shows a vertical section of trough 5, the lower diagram a horizontal section; 6 and 7 are a series of hollow electrodes, made of graphitized carbon and covered with a protecting coating. They are so arranged that the matte flows slowly between their ends, while water-gas is forced through the holes in the electrodes into the molten bath. Water-gas is used "on account of the hydrogen and carbon monoxide contained in it. The hydrogen combines with the sulphur in the matte to form a gas, which passes off, while the carbon monoxide serves to reduce and separate the iron in the ordinary manner. The electrolytic action of the current on the fused matte causes the iron to be drawn toward one electrode and the copper toward the other, and I utilize this action to separate these two metals. For this purpose I place a splitter 8, of plow shape, at the mouth of the trough, in such a position that the iron will be deflected toward one side and the copper toward the other, thus separating them. The copper will contain the precious metals, if such are present. In practice the iron collects in the metallic state in lumps or masses in the mouth of the trough at one side of the splitter and is drawn out by the operator. The copper drops from the other side and chills in lumps of bullion."

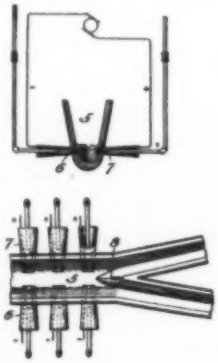


FIG. 2.—TREATING MOLTEN MATTE.

Production of Metallic Calcium.—W. Borchers and L. Stockem, 808,066, Dec. 26, 1905. Application filed Oct. 24, 1902.

Fused calcium chloride is electrolyzed with a comparatively small cathode against a large anode. The cathode is artificially cooled, so as to keep the temperature of the electrolyte in its neighborhood at a moderate red heat, not exceeding the melting point of metallic calcium. Under these conditions calcium is deposited in the shape of a soft sponge upon the cathode. If the sponge is taken out by means of a spoon, etc., and immediately dumped into kerosene oil to prevent oxidation of the spongy calcium by the oxygen or the moisture of the air, a crude metal is obtained containing from 50 to 60 per cent of pure calcium, the rest being adhering calcium salts. If, however, the deposited sponge, before lifting it out of the electrolyzing vessel, is caught by a pair of hot tongs and pressed between the jaws, the larger part of the calcium salt enclosed in the pores of the sponge will squeeze out, and the spongy mass will weld together into a solid plate, which may be taken out of the electrolyte and cooled without serious danger in the open air.

Producing Caustic Alkalis and Chlorine.—H. S. Blackmore, 809,085, Jan. 2, 1906. Application filed July 22, 1903.

H. S. Blackmore, 809,088, Jan. 2, 1906. Application filed May 10, 1905. Patent 809,085 covers the apparatus, patent 809,088 the process. Fig. 3 shows the arrangement for a molten electrolyte. The iron vessel 1 on the right hand of the diagram serves for the electrolysis of fused sodium chloride, a mass of molten lead 23 being the cathode, and the graphite rod 24 the anode. The cell is divided into an anode and cathode compartment. The anode compartment is in the center, and has a cylindrical form, being closed at the bottom by a porous diaphragm (of broken magnetite 22 resting on iron-wire gauze 21). The diaphragm floats upon the molten lead cathode and remains in close contact with it, notwithstanding considerable change in the surface level of the molten lead. Above the diaphragm the cylindrical anode chamber is filled with fused sodium chloride. The chlorine, set free at the anode, is drawn off through pipe 27. The lead-sodium alloy produced at the cathode being lighter than lead, is continuously displaced as formed from the surface of the cathode beneath the diaphragm, and rises to the surface of the cathode around the anode chamber, this being at a higher level than below the diaphragm.

The sodium of the alloy is continually converted into its hydrate or oxide, the remaining lead being returned by gravity to the bottom of the vessel 1 beneath the diaphragm, to receive further additions of sodium. For this purpose an annular pipe 29 is provided below the surface of the molten lead; it is arranged around and concentric with the anode chamber. This pipe has two rows of downwardly and outwardly opening perforations 30. Connecting with pipe 29 is a pipe 31, having valve 32, which serves for the introduction of molten sodium hydrate, which is injected in a plurality of fine streams into the molten lead-sodium alloy, and is reduced by the sodium to sodium oxide with evolution of hydrogen, passing out through 33. To facilitate the oxidation of the sodium, a layer 60 of loose granular iron, magnetite or ferro-

silicon, is arranged near and beneath the surface of the cathode around the anode chamber. This serves to distribute the streams of sodium hydrate rising from pipe 29, and bring them into thorough and intimate contact with the sodium in the alloy. The oxidizing action is facilitated by the innumerable local couples, due to the presence of the particles of iron, etc.

The sodium oxide thus formed is continually drawn off into a second vessel 35, and is now converted into hydrate. For this purpose a pipe 41 leads upward from beneath the level of the molten oxide in 35, past a steam injector 42, which serves both to introduce the water necessary for hydration and to carry the old material upward to a third vessel 43. The bent upper end of the pipe 41 contains a spring-closed air-inlet valve, to prevent any siphoning of hydrate back to 35. Such amount of sodium hydrate as is required to oxidize the sodium

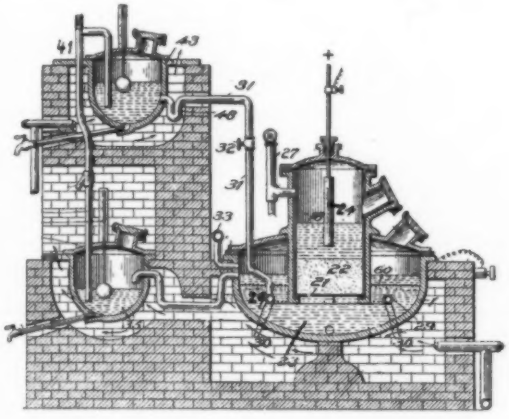


FIG. 3.—ELECTROLYSIS OF FUSED SODIUM CHLORIDE.

from the sodium-lead alloy, continually passes off from vessel 43 through a trapped outlet 48, communicating with pipe 31. The apparatus may be modified so as to be suitable for electrolysis of an aqueous solution of sodium.

The successive steps of the whole scheme of getting chlorine and caustic soda by electrolyzing fused sodium chloride are indicated by the following three equations:

$$mNaCl + nPb = mNa, nPb + mCl$$
$$mNa, nPb + mNaOH = mNa_2O + nPb + mH$$
$$mNa_2O + mH_2O = 2mNaOH$$

Production of Caustic Alkali and Chlorine.—H. S. Blackmore, 809,089, Jan. 2, 1906. Application filed May 10, 1905.

An aqueous solution of sodium chloride is electrolyzed with a mercury cathode, and in a separate vessel sodium hydrate is produced from the sodium amalgam. The chief feature of the process is that the movement of mercury and amalgam through the various vessels is effected solely by the differences of level of the various bodies of mercury and amalgam, and is entirely automatic. The apparatus is shown in vertical and horizontal section in Fig. 4. The vessel 1 contains mercury, and the valve 8 in outlet 2 is controlled by the lever 6 and ball-float 4, which serves to maintain a uniform lever of mercury in chamber 3. This mercury is made cathode by the connection 13', and communicates through the manifold 10 and several outlet pipes 11, with the mercury 13 at the bottom of the electrolyzing cell, which contains an aqueous solution of sodium chloride 14 above the mercury. Solid sodium chloride in the two receptacles 22, which are through openings 23 in communication with the electrolyzing cell proper, maintains the solution in saturated condition; 19 are the anodes. The chlorine gas, set free at the anodes, is led off through 20 and 21. The sodium amalgam formed at the cathode increases the bulk of the mercury until it rises above the level of the outlet pipe 25, whereupon it overflows and drops through a layer of carbon tetrachloride in vessel 26, and accumulates and passes out into the oxidizing vessel 28 through pipe 27. The carbon tetrachloride (or carbon bisulphide, etc.) in 26 prevents a short circuit between the mercury in the electrolyzing and in the oxidizing vessel 28. The latter is divided into a number of parallel compartments, alternately communicating at op-

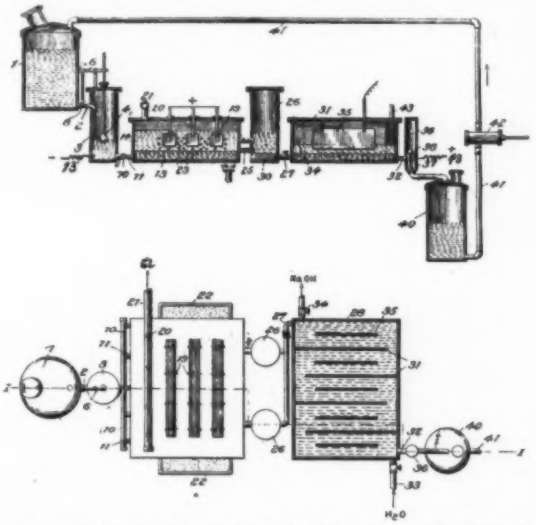


FIG. 4.—ELECTROLYSIS OF AQUEOUS SOLUTION OF SODIUM CHLORIDE.

posite ends by vertical baffle-plates 31. The liquid amalgam is introduced by pipe 27 into one end of the compartments, and flows in zigzag form to the outlet pipe 32. Adjacent to, but above this outlet 32, is an inlet pipe 33 for water, which flows over the amalgam; the resulting sodium hydrate escaping through outlet pipe 34. The rate of oxidation is increased by placing carbon electrodes 35 in the water and connecting them electrically with the amalgam below, either directly or by connecting the amalgam with the positive lead 43 of the electrolyzing current and the carbon electrodes with the negative lead. Pipe 32 carries the pure mercury from the oxidizing cell into the cylinder 36, in the bottom of which is a valve-outlet 37, controlled by a float 38. The mercury then collects in vessel 40, and is returned by means of pump 42 through pipe 41 to reservoir 1. After the electrolyzing current is turned on the whole procedure is automatic, due to the differences of level in the various bodies of mercury and amalgam, and these differences are maintained by suitable predetermined adjustment of float-feed 8 and float-controlled outlet 37, and of the height of the connecting pipes.

Diaphragm Cell.—H. Koller and P. Askenasy, 809,116, Jan. 2, 1906. Application filed Oct. 29, 1903.

If the anodic product is a gas and insoluble in the electrolyte, detrimental secondary reactions, due to the catholyte passing into the anode compartment, may be avoided, according to the inventors, by systematically lixiviating the diaphragm, or using a diaphragm of such a construction that the electrolyte which is introduced into the anode compartment is forced to flow over to the cathode compartment "in a direction substantially at right angles to the line of diffusion." If the diaphragm is constructed, for instance, of wedge-shaped parts, superposed as shown in Fig. 5 (the upper diagram being a cross-section through line 33 of the lower diagram), the electrolyte is caused to flow in zigzag from the anode to the cathode. On its way it meets, first, those parts of the diaphragm which are least impregnated with cathode lye. The fresh electrolyte absorbs the detrimental cathode lyes and carries them along back to the cathode. This results in a sys-

tematic lixiviation of the diaphragm; *p* is the anode, *n* the cathode. The electrolyte is introduced through pipe *e*, which is provided on its sides with openings *d*. It flows freely through the interstices *b*. The channels *g* facilitate the flow of the electrolyte. In an ordinary diaphragm cell, at a temperature of 60° C. and at 4.5 volts, the inventors obtained a cathode lye of 90 grams, NaOH per liter, with a current efficiency of 92 per cent. By substituting a diaphragm of their own concentration they obtained, with the same current and voltage, a concentration of 189 grams, NaOH per liter, with a current efficiency of 87 per cent; it was possible to increase the concentration to 120 grams NaOH per liter, but the current efficiency decreased simultaneously to 65 per cent.

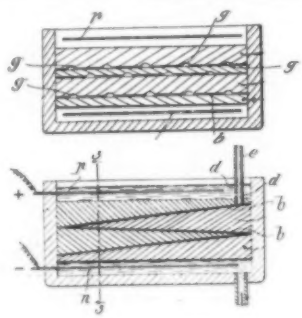


FIG. 5.—DIAPHRAGM CELL.

Production of Organic Compounds by Oxidation.—W. Lang, 808,095, Dec. 26, 1905. Application filed Aug. 28, 1902.

The inventor oxidizes organic compounds by means of manganic-oxide salts (generic formula Mn_2R_3), which are thereby reduced to manganous-oxide salts. The latter are then reoxdized by electrolysis; since manganic-oxide salts "are not subject to reduction at the cathode, a simple cell without a diaphragm may be used. The process is intended chiefly for the production of aldehydes, ketores and quinores. The following example is given: As starting point mangano-ammonium sulphate is used, which may be obtained in the shape of yellow anhydrous crystals from a hot acid solution with an excess of ammonium sulphate. Its formula is $MnSO_4 \cdot \frac{1}{2}(NH_4)_2SO_4$, and on the addition of cold water it splits up into $MnSO_4(NH_4)_2SO_4$ + aq and $MnSO_4$ + aq. The inventor mixes 47.5 kg. of mangano-ammonium sulphate together with 45 kg. of water and 75 kg. of 98 per cent sulphuric acid in a lead-coated receptacle provided with a stirrer, and subjects the mixture to electrolysis with an anodic current density of 3.5 amps. per square decimeter. The lead coating of the vessel serves as anode; the cathode is also made of lead. After 6,000 ampere-hours the manganese is present as a manganic-oxide salt; *i. e.*, as ammonium-manganese alum, the greatest part of which is separated out in a state of very fine division. This dark-red salt undergoes decomposition when brought together with water, thereby forming manganic oxide in the shape of brown flakes. After the water evaporated during the electrolysis has been replaced, the entire electrolyzing mixture is stirred together with 4 kg. of toluene in a closed lead-coated receptacle, provided with a stirrer, the temperature being maintained at about 50° C. During the reaction about 8 kg. of water are gradually added. After 2 or 3 hours the reaction is complete, and the solution and the undissolved salt have become perfectly clear. The oily mixture is driven out by passing steam through the vessel, and is worked up in the usual manner. The manganese mixture goes back for repeated electrolysis. From the oily mixture about 0.6 kg. of toluene are recovered, and about 3.7 kg. of benzaldehyde are obtained, "which is over 80 per cent of the theoretical quantity in relation to the toluene consumed." With a more dilute acid, benzoic acid would be formed besides the aldehyde; while a stronger acid would lead to an increased quantity of condensation products, but would accelerate the reaction. If the sulphuric acid is considerably stronger than 70 per cent, the electrolytic oxidation does not take place. If it is too dilute, pyrolusite and permanganic acid are produced at the same time. Similar effects are produced if, instead of toluene, its higher homologues are employed, and many substituted toluenes behave in the same manner. Isvengenol is oxidized to vanillin. In case the products of oxidation cannot be driven out with superheated steam they may be shaken out with a solvent which is insoluble in water. The process is stated to be of extensive application in the aliphatic series. For instance, methyl alcohol is oxidized either to formic aldeheyde or to formic-acid.

Production of Hydrochloric Acid.—I. L. Roberts, 807,640, Dec. 19. Application filed June 25, 1895. Assigned to Roberts Chemical Co.

Electrolysis of sodium chloride yields (besides caustic soda) chlorine and hydrogen gases in equivalent proportions. The gases are conducted in separate streams to a common point, where they impinge directly upon each other and are burned, one supporting the combustion of the other without the presence of any other gas. The resulting hydrochloride acid gas is conducted off to receivers containing water, by which the gas is absorbed. (The Roberts Chemical Co. are using this process at Niagara Falls for the production of caustic potash and hydrochloric acid from electrolysis of potassium chloride.)

Zinc Plating.—G. L. Meaker, 808,103, Dec. 26, 1905. Application filed June 18, 1902. Assigned to American Steel & Wire Co., of New Jersey.

An adhering and coherent coating of zinc with the desired metallic lustre is obtained by electroplating with the following electrolyte: 450 gallons of water are mixed with 500 pounds of commercial muriatic acid of about 18° Baume, and then 200 pounds of commercial sulphuric acid of about 66° Baume are added, in which is suspended metallic zinc until a saturated solution is formed. By adding sufficient water, the density is reduced to about 9° Baume, whereupon 1 pint of a saturated solution of a vegetable acid—such as oxalic acid, citric acid and tartaric acid and the like—is added to each gallon of the zinc solution.

Separating Galvanoplastic Deposits from Metal Matrices.—E. Albert, 808,331, Dec. 26, 1905. Application filed June 21, 1905.

The process is specially intended for electrotypers, and the object is to provide such an easy separation that both the electro and the matrix are uninjured. For this purpose sudden heating in (or floating upon) a metallic bath is employed, which causes the electro to spring off from the matrix. The inventor uses a metallic bath with a considerably lower fusing point than that of the metal matrix, and heats it almost up to the fusion point of the metal matrix. In electrotyping, with copper deposits and a lead matrix, the bath may comprise the ordinary backing metal (fusion point 220° C.), or an alloy of 57 parts of lead and 33 of tin (fusion point 150° C.). "In many cases the fusing point of the backing metal will be sufficient to effect the separation, and, accordingly, the separation may be effected simultaneously with the casting of the backing metal upon the deposit. The tinning of the deposit, which is done in order to secure the backing to the matrix, may be effected by placing the leaflets or foils of tin upon the deposit after its deoxidation, and thus the deposit may be tinned over simultaneously with the detaching of the same from the metal matrix.

Electrolytic Production of Lustrous Metallic Coatings on Metals.—A. Classen, 809,492, Jan. 9. Application filed Sept. 28, 1905.

The object of the inventor (who is best known through his work in electroanalysis) is to produce directly by electrolysis a firmly adhering deposit with a bright metallic lustre, without heating or polishing. It is said that iron plates coated with zinc by his method can be bent to any extent without the zinc splitting off. The object is obtained by adding to the electrolyte "a certain quantity of glucoside, or a substance classed among the glucoside, or an extract of plants, roots, barks, seeds, such as Althæapanama or licorice extract, which con-

tain the said substances or their derivatives, such substances being used either singly or in combination." For zinc coatings the following recipe is given: To the electrolyte, consisting of 20 kilograms of crystallized zinc sulphate, 4 kilograms crystallized sodium sulphate, 1 kilogram zinc chloride, and 0.5 kilogram boric acid in 100 liters water, is to be added the extract of 5 kilograms licorice root.

Electroplating Apparatus.—A. W. L'Hommedieu, 809,309, Jan. 9, 1906. Application filed April 22, 1905.

A barrel for electroplating small articles in quantities. It is revolved upon an axis laterally inclined from a vertical plane. The anodes are secured near the inner surface of the barrel, while one or more resident cathodes are provided near the axle. The articles to be plated are tumbling around, and are held in contact with the resident cathode, and are prevented from making contact with the anode by means of a perforated receptacle of non-conducting material.

Agitation of Electrolyte.—W. C. Wood and B. Oaksford, 808,789, Jan. 2, 1906. Application filed Aug. 31, 1905.

To agitate the solution used in the electrodeposition of metals, the inventors use the arrangement shown in Fig. 6. At the bottom of the tank *a* are one or several troughs *b*. The perforated plungers *c* fit into and slide within the troughs *b*. By reciprocating the plungers the electrolyte is pressed through the holes in the same and thus agitated.

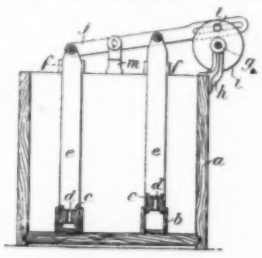


FIG. 6.—AGITATION OF ELECTROLYTE.

Electrolytic Deposition.—P. Steenlet, 807,973, Dec. 19, 1905. Application filed Nov. 7, 1903.

The inventor claims that in electroplating a very material improvement ("an increased and regular deposit") results from adding to the electrolyte small quantities of certain organic materials, as albuminoids, but that when these added materials get occluded in the deposit, the latter is rendered brittle and irregular. He claims he can get the good effect without the bad one, "by employing a diaphragm impregnated with or otherwise made to carry in suitable disposition and quantity the organic substance, which latter is rendered insoluble."

Treating Hides.—F. B. Hinkson, 807,930, Dec. 19, 1905. Application filed Dec. 27, 1904.

Details of construction of an electrolytic tank with a series of bars supporting the hides, and a series of electrodes in parallel with them. The direction of the electric current through the tanning solution is automatically reversed in certain intervals.

Asymmetric Cell; Aluminium Electrolytic Valve.—M. Buettner, 809,770, Jan. 9, 1906. Application filed Aug. 4, 1904.

For electrolytic rectifiers and condensers with aluminium electrodes an electrolyte consisting of a solution of caustic ammonia and boric acid is used. "It is not necessary that the solution contain the substances in the proportion of their chemical equivalents, as more or less of either substance can be used."

Treating Hides.—F. B. Hinkson, 810,144, Jan. 16, 1906. Application filed Dec. 27, 1904.

The claim reads: "A process of treating hides which consists in suspending a plurality of hides between a plurality of electrodes in such manner that each hide is disposed between one pair of electrodes, passing an electric current transversely through each hide, and reversing the direction of the current at suitable intervals."

Purifying and Filtering Water.—L. Dion, 808,350, Dec. 26, 1905. Application filed July 29, 1904.

Details of construction of an apparatus in which the water is first subjected to electrolytic action between two series of vertical electrodes and then passed through a filter.

BATTERIES.

Dry Cell.—C. Jaeger, 808,755, Jan. 2, 1906. Application filed Feb. 27, 1904.

A battery cell having a zinc cup, a carbon pencil within the cup. A compound of dioxide of manganese, iron filings and powdered graphite, containing in solution "ammonia calcidium," ferrocyanide of potash, alcohol and chloride of zinc, surrounds the carbon pencil. The remaining space is filled with flour and plaster of paris.

Storage Battery Plate.—D. P. Perry, 809,742, Jan. 9, 1906. Application filed June 8, 1903.

The grid comprises three flat superimposed lead plates. The two outer plates are provided with a plurality of vertical columns of obliquely-arranged outwardly-tapering apertures, the obliquely-arranged aperture of one plate being arranged at an angle to those of the other plate. The intermediate plate is provided with evenly-distributed small openings.

Electric Cell.—K. Tsukamoto, 809,647, Jan. 9, 1906. Application filed Jan. 14, 1904.

The cell has an outer zinc cylinder, and inside a hollow porous carbon tube, filled with the following depolarizing mixture, 240 grams graphite, 160 manganese dioxide, 8 potassium chloride, 20 potassium permanganite, 50 ammonium chloride are boiled with 500 grams of a saturated solution of potassium permanganate and pressed to a definite form. A fibrous substance, or blotting paper, is bound around the carbon tube, and the space between the inner surface of the zinc shell and the blotting paper is filled with a mixture, consisting of 100 grams ammonium chloride, 8 potassium chloride, 400 gypsum, 1 mercuric sulphate, and 500 dextria, well mixed and dried. When the cell is to be used water is added.

DISCHARGES THROUGH GASES.

Manufacture of Nitric Acid.—H. Pauling, 807,491, Dec. 19, 1905. Application filed April 2, 1902.

Atmospheric air is subjected to spark discharges, whereby the nitrogen of the air is completely converted into N_2O_3. The mixture of gases thus obtained is mixed with fresh atmospheric air, and the whole is exposed in another apparatus to the influence of dark electric discharges. The oxygen of the air is thereby converted into ozone, which in forming is combined with the nitrogen trioxide formed in the first process, and thereby forms anhydrous nitric acid:

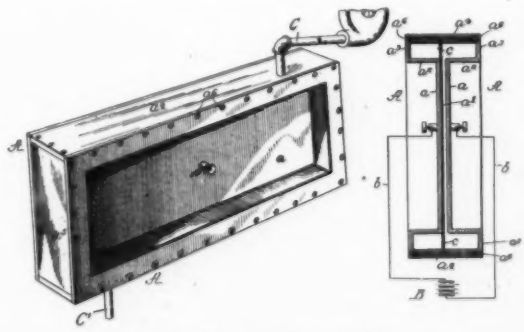


FIG. 7.—PRODUCTION OF OZONE.

$$N_2O_3 + 2O_3 = N_2O_5 + 2O_2$$

Upon adding water, nitric acid is obtained by $N_2O_5 + H_2O = 2HNO_3$. In order to form nitric acid directly,

$$N_2O_3 + H_2O + 2O_3 = 2HNO_3 + 2O_2$$

the air may be charged with moisture before undergoing the electrical treatment. To this end the air is conducted through a vessel filled with water, where it is charged with moisture, and then into the electrical apparatus.

Production of Ozone.—William P. Rice, 807,964, Dec. 19, 1905. Application filed May 9, 1904. Assigned to National Ozone Co.

The apparatus is a closed box of the construction shown in Fig. 7; a a_2 a_3 are thin metal plates, a_4 and a_5 insulating strips. The silent discharge takes place between the flat parallel plates, a through the air gap a^1. A glass plate c is placed against one of the electrodes. The air is introduced through C, and the ozonized air is carried off through C^1. A modification is also described which permits treatment of the air under pressure. Since both electrodes a a are exposed to the direct cooling action of the atmosphere an undue rise of the temperature is prevented.

SYNOPSIS OF PERIODICAL LITERATURE.

A Summary of Articles Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Tin Refining.—The conclusion of the articles by Dr. H. Mennicke has appeared in the *Elektrochemische Zeitschrift* of December. The author used alloys of tin, 60 per cent, and lead, 40 per cent, as anode in tin fluosilicate solution, leave a residual alloy of tin 30 per cent and lead 70 per cent, with a 45 per cent current yield of tin. Lead which went into solution deposited on the cathodes, but it was noticed that up to a certain concentration lead did not deposit out on the cathode. The question then arose whether lead-tin alloys could be refined, if the solution was always kept below a certain percentage of lead by some other process, which might be complete electrodeposition of the lead and tin, or by precipitation with hydrofluoric acid, or sodium chloride, sodium sulphate, etc. The author's work shows that the electrolytic refining of "work-tin" with a tin fluosilicate solution would be practicable and profitable. In comparison with electrolytic refining of lead, tin is under disadvantage of a smaller market, and has not the quantities of precious metals lead is apt to have, while the advantages are the preparation of chemically pure tin, which commands a higher price and is especially suited for making tin salts, tin oxide, etc. Comparative experiments showed that tin fluoride-hydrofluoric acid and tin fluoride-fluosilicic acid solutions give solid deposits, with a higher current yield than tin fluosilicate-fluosilicic acid solutions. As pointed out, these former solutions may not be used for alloys, on account of the character of the anode residue, but are suitable for work tin. The author tried steel cathodes, and found they were somewhat attacked, and that the resulting solutions gave spongy tin. He also noted that the presence of free acid tends to make the tin deposit more spongy, and also when the acid went below 1 per cent. From 2 per cent to 12 per cent the deposits are solid. When refining anodes of solder the antimony and copper contained do not dissolve, only the lead and tin, and as soon as lead begins to separate with the tin (after reaching a certain concentration) the deposits get spongy. With more lead in the anodes, as the solution approaches in composition the Betts lead electrolyte, the deposit becomes stronger again. The author believes a seperation of lead and tin with this solution would be practicable only if the lead is repeatedly removed from the solution by precipitation, and then the lead would be won only as a lead salt. Experiments along this line, especially with sulphuric acid as precipitant for lead, gave negative results. The author found that compressed tin-sponge behaved well as anode. The conclusions of the author are as follows:

1. The preparation of the tin electrolyte is much more difficult than that of the corresponding lead solution.
2. The removal of hydrofluoric acid from the solution is not necessary.
3. The regeneration and purification of electrolyte is more difficult than in the Betts lead process.
4. The current yield is lower than in Betts process.
5. Solid refined tin can be obtained under certain conditions.
6. The electrolytic refining of tin is economical in the absence of much lead. The removal of copper, bismuth and antimony is easy.
7. The extraction of tin from lead-tin alloys is possible, but not economical.
8. A combination of electrochemical and chemical processes for refined lead alloys is not economical.

Conclusions 1 and 3 would have to be modified if the author used for the preparation of solutions a diaphragm cell with tin as anode in a solution of fluosilicic acid, while hydrogen is liberated at the cathode.

Welding by Acetylene.—In the *Bulletin* of the Italian Engineers and Architects, Mr. Memmo has recently discussed the welding of metals with acetylene gas. According to an abstract in the London *Electrical Review*, Dec. 29, the author found the following arrangement for getting a mixture of the acetylene and oxygen gases for the production of the oxyacetylene flame very satisfactorily: He passes the two gases through several extremely fine tubes, contained in one large tube, beyond the T piece connected to the separate acetylene and oxygen holders, and this has afforded excellent results, when working with an initial pressure equivalent to 1 or 1½ meters of water. When intending to use this apparatus, rubber tubes are connected between the receptacles containing the oxygen and the acetylene, both of which must be provided with pressure regulators, and on the acetylene tube there should also be provided a non-return valve, so that under no circumstances can the greater pressure of the oxygen gas cause it to invade and become mixed with the acetylene in the generator or holder of the latter; such a mixture might be extremely dangerous. The spear-like flame should have a diameter of 3 to 4 millimeters, and a length of 10 to 15 millimeters. If there is too much acetylene, there will be a luminous white sheath due to the free carbon. With an excess of oxygen, the flame becomes too clear, and there is the probability of frequent extinction of the flame. With care in the quantitative adjustment of the gases, an extremely neat weld can be effected in about one-fourth of the usual time. Experiments made on welded steel show that the results are as strong as those obtained by electrical welding. Examples are given of practical work done in repairing boiler plates by welding in new portions, and in repairing a vulcanising machine worked at a pressure of 5 atmospheres. The high temperature effects the fusion of platinum and all the other more refractory metals. Whilst approaching the high temperature of the electric arc, acetylene admits simple means for the regulation of the working temperature.

Electric Induction Furnace.—In the "Jour. Soc'y Chem. Ind." of Oct. 31, a French patent (353,391, April 15, 1905)

granted to Soc. d' Exploitation des brevets Dolter is mentioned. There is a single single-phase transformer. Around each of its two vertical legs the primary coils are wound. Around each of these primary coils, but, of course, properly insulated from them, a closed secondary is provided, but the central legs of these two secondaries (inside the transformer core) are made into one. The cross-section of the secondary is, therefore, ꝏ — shaped. The transformer is made in two separate movable pieces; one portion consists of the upper horizontal part of the core, together with the two vertical legs with the primaries; they fit into appropriate cavities in the stonework of the furnace. The other portion is the lower horizontal part of the transformer core, which completes the magnetic circuit; it is carried on a wagon. A single transformer may thus be used to serve a series of such furnaces.

Electric Glass Furnace.—In the "Journal de l' Electrolyse" of Sept. 15, an electric furnace of Sauvageon for glass manufacture is described and illustrated. It is a continuous resistance furnace. The cross-section of the charge varies according to the heat to be produced in different compartments of the furnace. The author gives some theoretical calculations, to show that the use of an electric furnace is profitable in this case. Another description of the same furnace may be found in the September issue of "L' Industrie Electro-Chimique."

Electrolysis of Water.—A summary of the phenomena of the electrolysis of water with a discussion of the theoretical problems involved and a description of some commercial types of electrolyzers for the production of hydrogen and oxygen is given by J. W. Richards in the November issue of the "Journal of the Franklin Institute."

Castner Mercury Cell.—M. Le Blanc and C. Cantoni have studied the Castner mercury cell for electrolysis of alkali chlorides, and describe in "Zeit. f. Elektrochemie," Sept. 8, a construction suitable for laboratory experiments. At a current density of 0.1 amp. per square centimeter, with slow movement of the mercury and with high concentration of KCl, they obtained an ampere-hour efficiency above 90 per cent, the temperature being up to 40° C.

Electrolytic Meters.—Two new electrolytic meters were described by S. H. Holden before the Birmingham Section of the British Institute Electrical Engineers. The paper is printed in full in the London *Electrician* of Dec. 22. The first meter is of the simple type of gas voltameter, the whole current passing through the meter. A caustic soda solution is used with nickel electrodes, and an old suggestion of Bunsen is made use of to weigh the electrolyte and use its loss of weight as a measure of the coulombs instead of the volume of evolved gases. In the second meter only a portion of the total current is sent through the meter. For a meter to be shunted, the first condition is that the current passing through it is exactly proportional to the difference of potential between the terminal electrodes. In other words, non-polarizable electrodes must be used. The author uses hydrogen electrodes, that is, platinized platinum electrodes, saturated with hydrogen, which are well known from scientific research, but have not been used before for practical purposes. The current is in this case proportional to the potential difference, provided that oxygen is not produced faster at the anode than the anode can absorb hydrogen from its hydrogen atmosphere to form water. This condition is easily realized in practice. Fig. 1 shows the essential parts of this meter. It consists of a vertical tube with bulb attached.

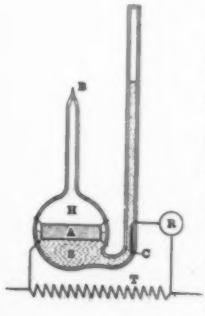


FIG. 1.—ELECTROLYTIC METER.

C is the cathode, a platinum wire covered with platinum black. *A* is the anode of sheet platinum, also covered with platinum black. *S* is the electrolyte, consisting of a 10 per cent solution of sulphuric acid, and *H* is an atmosphere of hydrogen. *R* is a resistance coil equal to about 10,000 ohms. *T* is the shunt, which in a 5-amp. meter has a resistance of 0.2 ohm. To start the meter it is held with the tube nearly horizontal and below the bulb. All the gas then collects in the bulb, while the tube fills with electrolyte, which remains in it, after it is restored to the vertical position for use. When a current is passed through the shunt a steady, fine stream of gas bubbles rises from the cathode gradually, and replaces the liquid in the tube. This gas is measured.

Ozone.—A paper by E. Warburg, abstracted in *Physikalische Zeit.*, Jan. 1, discusses the different factors which may increase the efficiency of the production of ozone from oxygen by silent discharges, under the supposition that the zone of the formation of ozone is limited to the luminescent portion of the gas. With a given amount of electricity, the endeavor should be to bring as large a part of the gas to luminescence. Further the increase of temperature, and, therefore, the current density in the zone of formation of ozone should be as small as possible, since the expansion of the gas, due to the increase of the temperature, is unfavorable. Finally, the concentration of ozone in the zone of formation of ozone should be as small as possible.

THEORETICAL AND EXPERIMENTAL.

Electrolytic Estimation of Cadmium.—In the December issue of the "American Journal of Science," C. P. Flora gives some additional notes on the estimation of cadmium with the aid of a rotating cathode, and then summarizes the results of his work on this subject as follows: Cadmium taken in the form of the sulphate may be very accurately and satisfactorily estimated by deposition from solutions containing sulphuric acid, sodium acetate and acetic acid, or potassium cyanide; but little less satisfactorily from solutions containing urea, formaldehyde or acetaldehyde; and also, with proper precautions, from solutions containing pyrophosphates, phosphates, tartaric acid or formic acid. From solutions containing oxalates or oxalic acid, ammonium tartrate, or potassium formate, however, the author was unable to obtain satisfactory deposits. When taken as the chloride, cadmium does not permit such a wide range of conditions. Nevertheless, from solutions of the chloride containing sulphuric acid or potassium cyanide, or the pyrophosphates, the metal is deposited in a form comparable with that obtained when cadmium sulphate is taken. Solutions of the chloride of cadmium, to which is added hydrogen disodic phosphate, gave less desirable results, while solutions containing urea, formaldehyde or acetaldehyde, gave deposits free from sponginess only after careful regulation of the conditions. In addition to the solutions containing the oxalates, oxalic acid, the formates and the tartrates, negative results were obtained in the case of the chloride by solutions containing the acetates, formic acid and tartaric acid. The nitrate of cadmium is ill-fitted for electrolytic estimation, the cyanide solution being the only one from which satisfactory results were obtained. From solutions containing 1 per cent or more of free nitric acid the cadmium is not deposited by the current. The same issue contains a note by the same author on the estimation of cadmium as the oxide.

Solution of Platinum in Sulphuric Acid by Alternating Currents.—This problem has been studied very carefully by R. Ruer, who gives his results in "Zeit. f. Elektrochemie," Oct. 13. In the electrolytic solution of platinum in sulphuric acid the effect of the cathodic half-wave of the alternating current may also be obtained by means of a reducing agent. In an analogous manner the effect of the

anodic half-wave may be obtained by means of an oxidizing agent. This proves that the solution of platinum in sulphuric acid by means of alternating current is equivalent to alternating oxidation and reduction. When platinum is made alternately cathode and anode in a sulphuric acid solution of 66 to 50 per cent by weight, it goes into solution only if an anodic potential above — 1.20 volt (against a hydrogen electrode in the same electrolyte) is impressed upon it. The higher the potential above this value the stronger the solvent action. With respect to the cathodic potential, the solvent action becomes strongest when the cathodic potential impressed on the platinum is — 0.7 volt. The behavior of platinum with alternating current shows a complete analogy with the phenomena of the passive state. All observations made by the author may be easily explained by the assumption of a peroxide film.

Electrolysis of Fused Nitrates.—The electrolysis of nitrates of potassium, sodium and lithium with different electrodes was studied by A. Bogorodski, who gives an account in "Jour. Russ. Phys.-Chem. Ges." Vol. 37, p. 703, an abstract being given in the issue of Oct. 31 of "Jour. Soc'y Chem. Ind." The author studied the various products of electrolysis under varying conditions, and especially the formation of peroxides of the metals.

Electrolytic Conduction and Specific Inductive Capacity.—The November issue of the "Jour. of Phys. Chem," contains a paper by J. H. Mathews on the relation between electrolytic conduction, specific inductive capacity and chemical activity of a large number of solutions. In many cases, at least, chemical action was found to be wholly independent of any electrochemical phenomena. The Nernst-Thomson rule has no foundation in fact and the exceptions are as numerous as the confirmations. A long and very useful bibliography on dielectric constants is added.

Glass.—In "Zeit. f. Elektrochemie," Sept. 22, E. Zschimmer discusses the physical properties of glass as function of its chemical composition. He shows that this is an extremely difficult problem and that it would generally lead to very wrong results to assume additive properties.

Dilute Amalgams.—A preliminary account of an experimental investigation by J. F. Spencer of the electromotive activity of dilute amalgams is given in "Zeit. f. Elektrochemie," Oct. 13.

Metallurgical Furnaces.

Losses of Heat by Radiation.—J. Bied relates in the *Revue de Metallurgie* for September, the results of experiments made to determine the losses of heat from the sides of a flue or furnace. He had boxes made of galvanized iron with a surface of 0.25 square meter, pressed closely against the brickwork, and water circulated through them. While the conditions do not represent exactly those of free radiation to the air, but rather of conduction to iron cooled by water, yet they are worth recording. The losses through refractory materials of various kinds and thicknesses, for varying differences of temperature, are given in kilogram calories lost per hour per square meter of radiating surface:

Nature of the Walls. (Thickness in Centimeters)	Difference of Temperature	Losses per Hour per m² in Calories.
14 c.m. alumina brick.....	500° C.	1,600 Cal.
	700	2,208 "
5 c.m. magnesium carbonate.....	700	2,506 "
Ditto—with 20 c.m. small cinders and 3 c.m. of cement.....	700	526 "
5 c.m. of lightly compressed infusorial earth	650	1,800 "
20 c.m. alumina brick.....	700	2,570 "
Ditto—with 20 c.m. small cinders....	700	900 "
45 c.m. magnesia brick.....	1,300	1,300 "
6 c.m. magnesium carbonate.....		
80 c.m. ordinary fire-brick.....	1,600	1,900 "

Electric Power from Coke-Oven Gases.—The London *Electrical Review* of Jan. 5 contains an abstract of a paper by G. J. Hooghwinkel, read before the Manchester Geological and Mining Society. The author first points out that the generation of electric power from the waste gases of blast furnaces has already proven a commercial success. He refers, for instance, to the gas plant at the Ilseder Iron Works, supplying also the necessary power to the Peine rolling mills near Hanover. The entire steel plant and rolling mills at Peine are driven by electric power generated from waste blast-furnace gases. He then passes over to a discussion of the use of the surplus gases from coke ovens direct in gas engines. He has found in many cases that the cost per unit kw-hour in coke-gas power stations of medium size was about 0.2 to 0.4 cent. The production of cheap power at collieries is a question gaining in importance every day proportionately to the drop in the price of the saleable article and the increased depth of the pits. The firing of steam boilers by means of small coal at the pit is an expensive and, if no rubbish and refuse from the washeries are available, a very wasteful process, having regard to the low efficiency of the boilers. Even taking the value of this small coal at $1.00 per ton at the pit's mouth, the saving of coal by using gas engines is a substantial item. Every modern colliery should, therefore, either burn its rubbish and waste in gas producers, or else compress and coke it in by-product ovens, using the gases obtained in both processes for generating electrical power by means of gas engines. The amount of power to be derived from a battery of 80 ovens of modern type, coking a charge of 7 tons in 32 hours, and using coke of a medium percentage of volatile matter, giving off about 7,000 cubic feet of gas per ton per hour, or in all 122,500 cubic feet per hour would be as follows: If the ovens used 70 per cent of the gases for heating the flues, there should remain about 36,000 cubic feet for power, and taking a consumption of 75 cubic feet per hp-hour, about 1,500 horse-power should be available, or nearly 20 horse-power per oven. This amount varies, of course, with the coal and the type of oven; and the author states he knows of cases where the power is nearly 30 indicated horse-power per oven. The paper is reprinted in the *Mining World* of Jan. 20.

Slags.

Heat of Formation of Silicates.—A very important piece of experimental laboratory work has been done by D. Tschernobaeff, at the suggestion of Prof. Le Chatelier, and reported in *Revue de Metallurgie* for October. In the oxygen bomb of a calorimeter were placed a mixture of charcoal, silica and the salt of the base to be studied. After combustion in the compressed oxygen there remained the silicate of the base, melted by the heat generated.

Barium Silicate.—The heat of the following reaction was measured:

$$BaCO^3 + SiO^2 = BaSiO^3 + CO^2$$
$$= -41{,}000 \text{ Cal.}$$

from which we have

$$(BaO, SiO^2) = BaO, CO^2) - 41{,}000$$
$$= 55{,}700 - 41{,}000$$
$$= 14{,}700 \text{ Cal.}$$

Calcium Silicates:

$$CaCO^3 + SiO^2 = CaSiO^3 + CO^2$$
$$= -27{,}300 \text{ Cal.}$$

Whence

$$(CaO, SiO^2) = CaO, CO^2 - 27{,}300$$
$$= 45{,}150 - 27{,}300$$
$$= 17{,}850 \text{ Cal.}$$

Again:—

$$2CaCO^3 + SiO^2 = Ca^2SiO^4 + 2CO^2$$
$$= -62{,}000 \text{ Cal.}$$

Whence

$$(2CaO, SiO^2) = 2(CaO, CO^2) - 62{,}000$$
$$= 90{,}300 - 62{,}000$$
$$= 28{,}300 \text{ Cal.}$$

Again:—

$3CaCO^3 + SiO^3 = Ca^3SiO^5 + 3CO^2 = -107{,}900$ Cal.

Whence

$(3CaO, SiO^2) = 3(CaO, CO^2) - 107{,}900 = 135{,}450 - 107{,}900 = \mathbf{28{,}550}$ Cal.

Strontium Silicate:

$SrCO^3 + SiO^2 = SrSiO^3 + CO^2 = -35{,}100$ Cal.

Whence

$(SrO, SiO^2) = (SrO, CO^2) - 35{,}100 = 53{,}000 - 35{,}100 = \mathbf{17{,}900}$ Cal.

Magnesium Silicate:

$(MgO, SiO^2) = \begin{cases} +329 \text{ Cal.} \\ +450 \text{ "} \end{cases}$

were two results obtained by directly burning a mixture of MgO, SiO^2 and carbon. The experimenter considers these results unreliable, and considers the heat of the formation of this silicate as not yet known.

Lithium Silicate:

$Li^2CO^3 + SiO^2 = Li^2SiO^3 + CO^2 = -24{,}900$ Cal.

Whence

$(Li^2O, SiO^2) = (Li^2O, CO^2) - 24{,}900 = 90{,}000\,(?) - 24{,}900 = \mathbf{65{,}100}\,(?)$ Cal.

Sodium Silicate:

$Na^2CO^3 + SiO^2 = Na^2SiO^3 + CO^2 = -30{,}400$ Cal.

Whence

$(Na^2O, SiO^2) = (Na^2O, CO^2) - 30{,}400 = 75{,}600 - 30{,}400 = \mathbf{45{,}200}$ Cal.

Aluminates of Calcium.—Seven experiments made with mixtures of Al^2O^3, $CaCO^3$ and carbon gave very small heats of combination, almost within the errors of experiment. They were

$(Al^2O^3, CaO) = 450$ Cal.
$(Al^2O^3, 2CaO) = 3{,}300$ "
$(Al^2O^3, 3CaO) = 2{,}950$ "

Aluminium Silicate.—This was determined very neatly. The heat of the two following reactions was determined, using calcined kaolin for the $Al^2Si^2O^7$:

$2SiO^2 + Al^2O^3 + 3CaCO^3 = Ca^3Al^2Si^2O^{10} + 3CO^2 = -101{,}900$ Cal.

$Al^2Si^2O^7 + 3CaCO^3 = Ca^3Al^2Si^2O^{10} + 3CO^2 = -116{,}800$ Cal.

Whence

$(2SiO^2, Al^2O^3) = 116{,}800 - 101{,}900 = \mathbf{14{,}900}$ Cal.

Calcium Silico-Aluminate (Gehlenite).—The first reaction given above enables us to calculate the heat of formation of the ternary compound so common in blast-furnace slags. Thus,

$(3CaO, Al^2O^3, 2SiO^2) = 3(CaO, CO^2) - 101{,}900 = 135{,}450 - 101{,}900 = \mathbf{33{,}550}$ Cal.

Kaolin.—By burning dry kaolin with carbon, the reaction was assumed to be during the burning off of the carbon:

$H^4Al^2Si^2O^9 = Al^2Si^2O^7 + 2H^2O$

And thence

$(Al^2Si^2O^7, 2H^2O) = 28{,}900$ Cal.
since $(Al^2O^3, 2SiO^2) = 14{,}900$ "
then $(Al^2O^3, 2SiO^2, 2H^2O) = \mathbf{43{,}800}$ "

Quartz.—It was attempted to measure the heat of transformation of quartz into amorphous, melted silica. The reactions were:

10 SiO^2 (quartz) $+ Na^2CO^3 = -9{,}600$ Cal.
10 SiO^2 (fused) $+ Na^2CO^3 = -8{,}700$ "

whence 10 SiO^2 (quartz) $= 10\ SiO^2$ (fused) $= -900$ Cal.
or 10 SiO^2 (fused) $= 10\ SiO^2$ (quartz) $= -900$ "

While some of the values given in this paper are very probably only first approximations, yet as such they are very welcome, and will be gratefully received by both theorists and practical metallurgists. A résumé is as follows, adding also the total heat of formation of the various compounds from their elements:

	Cal.		*Cal.*
(BaO, SiO^2)	= 14,700	(Ba, Si, O^3)	= 328,100
(CaO, SiO^2)	= 17,850	(Ca, Si, O^3)	= 329,350
$(2CaO, SiO^2)$	= 28,300	(Ca^2, Si, O^4)	= 471,300
$(3CaO, SiO^2)$	= 28,550	(Ca^3, Si, O^5)	= 603,050
(SrO, SiO^2)	= 17,900	(Sr, Si, O^3)	= 329,100
$(Al^2O^3, 2SiO^2)$	= 14,900	(Al^2, Si, O^5)	= 767,500
$(3CaO, Al^2O^3, 2SiO^2)$	= 33,550	$(Ca^3, Al^2, Si^2, O^{10})$	= 1,195,550
$(H^2O, Al^2O^3, 2SiO^2)$	= 43,800	(H^4, Al^2, Si^2, O^9)	= 927,420
(Li^2O, SiO^2)	= 65,100?	(Li^2, Si, O^3)	= 347,100?
(Na^2O, SiO^2)	= 45,200	(Na^2, Si, O^3)	= 326,100
(CaO, Al^2O^3)	= 450	$(Ca, Al^2, O^4,)$	= 524,550
$(2CaO, Al^2O^3)$	= 3,300	(Ca^2, Al^2, O^5)	= 658,900
$(3CaO, Al^2O^3)$	= 2,950	(Ca^3, Al^2, O^6)	= 789,050

COPPER AND BRONZE.

Oxidation by Fusion.—The German Bureau for Testing Materials, at Berlin, has published the results of an investigation on the oxidation of melted copper-tin bronze (*Revue de Metallurgie*, July, 1905). The tin oxidizes first, forming SnO^2; or, if Cu^2O is already present, the tin added reduces it, forming SnO^2. The latter solidifies throughout the mass as infusible crystals, making the bronze pasty. The crystals can be recognized in such oxidized bronze, under the microscope, as lozenge-shaped crystals or pellicules. The addition of 1.25 per cent of phosphorus to a badly oxidized bronze caused fluidity, and the disappearance of the SnO^2 crystals, 0.16 per cent of phosphorus remaining over in the deoxidized alloys.

Aluminium Bronze.—L. Guillet, in *Revue de Metallurgie* for Aug., 1905, gives a very thorough study of the alloys of aluminium and copper. His conclusions confirm, in general, those of Le Chatelier, proving the existence of Cu^2Al and Al^2Cu, and of intermediate eutectics. The article is a very complete résumé of present information about these alloys.

Magnalium.—Some notes on light alloys are given in London *Engineering* of Jan. 5. Magnalium, which is the name given to an alloy of aluminium with magnesium, is manufactured in three varieties—*X*, *Y* and *Z*. Alloy *X* contains copper 1.76 per cent, magnesium 1.60 per cent, nickel 1.16 per cent, and antimony and iron in smaller quantities. Alloy *Y*, which appears to be intermediate in composition between *X* and *Z*, except as regards nickel, contains copper, magnesium, tin, lead, a small amount of iron and a doubtful trace of antimony. Alloy *Z*, in the form of soft sheet, contains tin, 3.15 per cent; copper, 0.21 per cent; magnesium, 1.58 per cent; lead, 0.72 per cent, and about 0.3 per cent of iron. Magnalium has two advantages over pure aluminium, for its tensile stress is decidedly higher, and it behaves better when subjected to turning. The tensile strength ranges from 8½ to 10 tons in the case of ordinary castings. Some further notes on researches by Barnett on magnalium are given. G. I. Petrenko (*Zeit. Anorg. Chemie*, 1905) has investigated silver-aluminium alloys. From the complete fusion diagram constructed by him on Tammann's method, he shows that two distinct compounds of aluminium and silver exist—namely, $AlAg_2$ and $AlAg_3$. The melting point curve falls from the melting point of aluminium to the eutectic point at 567°, then rises to the melting point of silver; on the rising point of the curve are two breaks—at 721° and 11.15 per cent of aluminium, and at 771° and 7.72 per cent aluminium respectively, corresponding with the two compounds mentioned. Both exist in two polymorphous forms. The alloys, with from 7.72 to 11.3 per cent of aluminium, take a good polish; those with from 0 to 7.72 per cent of aluminium are quite stable in the air.

RECENT METALLURGICAL PATENTS.

In view of limitations of space only a few miscellaneous patents can be noted in this issue. The bulk had to be reserved for our next issue.

Roasting Furnace.—For cooling the shaft and stirring arms of a roasting furnace, Ottokar Hofmann (809,953, Jan. 16) makes them hollow, and uses a vertical water-pipe extending through the shaft with branch pipes, each of which enters one of the hollow stirring arms through an opening at the inner end, while at the outer end a spraying means is provided by which the water is delivered to the arm in the form of a spray or plurality of streams. The water evaporates rapidly and the steam goes off upwards through the vertical hollow shaft. If more water is injected than will be evaporated, it flows down the inside of the shaft, accumulates at the bottom and discharges by means of an overflow. The chief advantage is that the degree of cooling is under the complete control of the operator.

Heat in Solution.—If in the treatment of an ore or a metalliferous sand it is necessary to use a hot solution, W. J. Jackson (252,879, Jan. 2) proposes to supply the heat by adding a material which results in an exothermic reaction, so that heat is produced chemically within the solution itself. In case of an aqueous solution he proposes to add calcium oxide, the heat being derived from the formation of the hydroxide.

Oxide Ores of Nickel and Cobalt.—The New Caledonian nickel and cobalt ores, which contain the metal in the form of an oxide, are of themselves melted with difficulty and are very unsatisfactory in their working in a shaft furnace, as the greater part of them are in the form of powder or fines. It has been the practice to mix sulphur with the ores and then briquet the mixture and charge the briquets into the furnace, in order to form the matte. J. Savelsberg (810,572, Jan. 23) endeavors to avoid the briquetting step in the following way: The ores are mixed with sulphur or sulphur-bearing materials (sulphates, gypsum, sulphides) and flux, if necessary, and a suitable quantity of pulverized coal or coke, and the mixture is charged into a converter on a bed of glowing fuel or ore, and simultaneously force-blast is blown through the mass. The charge is so heated that the sulphur reacts upon the ores containing the metals to form sulphur compounds of these metals, and the sulphurous acid is reduced by the glowing carbon again to sulphur. These reactions during the process produce sufficient heat to bring the mass to the sinter, containing sulphides of the metals, and the sinter is then broken and charged into a shaft-furnace and melted down as usually.

Iron.—C. Ellis (Nov. 7) proposes to produce iron by feeding the ore through a rotary kiln in a way somewhat resembling that used in the manufacture of cement, and by applying to the ore a reducing flame produced from pulverized fuel. The difficulty is that in order to secure complete reduction the flame must have a high temperature and reducing nature. To accomplish this, C. Ellis employs two flame strata above the ore. The upper one, which is more remote from the ore mass, is maintained at a high temperature by the supply of plenty of oxygen or air. The lower flame, which is between the upper flame and the ore, and comes into direct contact with the ore, contains an excess of combustible matter, such, for instance, as carbon monoxide, and has, therefore, marked reducing properties.

Zinc Coatings.—In order to get resistant durable coatings of zinc, it is necessary to prevent the formation of the so-called "hard zinc" and zinc oxide. This object is obtained, according to P. and A. Gührs (804,006, Nov. 7), by incorporating with the zinc about 0.5 to 2 per cent of aluminium and less than 1 per cent of a metal producing great fluidity, like tin. In the preparation of this alloy it is necessary to first melt the aluminium and then add the zinc.

Reception to Dr. Ostwald.

Previous to this departure for Europe, after a season of lectures at Harvard, Columbia and elsewhere, Prof. Wilhelm Ostwald, of the University of Leipzig, Germany, has consented to meet the members of the New York Section of the American Electrochemical Society and their guests on the evening of Feb. 2 at the Chemist's Club, 108 West 55th Street. A number of prominent scientific men will make short addresses, and a souvenir will be presented as a tribute of affection from his former students and as a recognition of his services to electrochemistry by his admirers. Members of the affiliated scientific societies of the city are especially invited to be present.

BOOK REVIEWS.

Soils and Fertilizers. By Prof. Harry Snyder. Second Edition. Easton, Pa.: The Chemical Publishing Co. Price $1.50.

Our farming interests are the largest and most important of our great country. Proper scientific methods of agriculture will make not only "two blades of grass grow where one grew before," but will render the often dull and monotonous life of the farmer intensely and happily interesting.

Much has been done in the past few years throughout the United States in this line, following the thoughtful paternalism of Germany, with changes to suit the individualism suited to American conditions.

Prof. H. Snyder, of the University of Minnesota, has been a leader in this propoganda, and in his book, "Soils and Fertilizers," has given us evidently the ripe fruit of his professional activity. We regret that the subject, though cognate to ours, is not one to which we can give an extended review.

Gas, Gasoline and Oil Engines. By Gardner D. Hiscox. New York: The N. W. Henley Publishing Co. Price $2.50 net.

This book deals broadly with the subject of internal combustion engine. The treatment is both logical and detailed. The author first reviews the history of past progress and sketches the theory of the different cycles, etc. Practical engineering details are next set forth.

We are particularly interested in the chapters on producers, blast furnace and coke-oven gas. We have been long of the opinion that at some future date power will be generated at a gas-engine by-product coke-oven installation cheaper than at most water powers, and that this will have a strong influence on the industrial development of coke-producing centers. This book confirms this belief. The utilization of blast-furnace gas, of course, has been given much attention in this journal since first founded. Both these lines of probable progress have important bearing on the electrochemical industry as well as on the metallurgical industry.

However, for perfect reliability the steam engine still holds undisputed sway, although this reign is drawing to a close, for economy of fuel is the order of the day, and for this reason, if for no other, we commend this book to the metallurgist.

Electrolytic Dissociation Theory. By H. P. Talbot and A. A. Blanchard. 84 pages, illustrated. New York City: The Macmillan Co. Price $1.25.

This excellent little book, written by two members of the faculty of the Massachusetts Institute of Technology, presents in a clear and concise form the principal facts on which the dissociation theory is founded. While intended as an elementary text-book for college students, it is recommended to others who wish to obtain a working knowledge of this theory and its application to the methods of qualitative analysis. The chapter giving the list of the more common ions formed with their characteristics will prove of great help to the student in applying this theory.

Acetylene for High-Temperature Work in the Laboratory and Workshop.

In our last issue (page 28) we noticed that the use of the oxyacetylene flame for welding and repairing iron and steel is now attracting considerable attention in Europe. In this country Mr. John Harris, of Cleveland, has been one of the chief pioneers of the use of acetylene for general heating purposes in laboratory and workshop practice. His exhibit at the acetylene convention three years ago, demonstrating the very high temperatures which may be easily produced by the oxyacetylene flame, first attracted the attention of the general engineering public to the great possibilities of this system. The results of his experimental work are now being placed on the market in form of a series of practical and handy heating devices by the Harris Calorific Co., of Cleveland, Ohio.

The oxyacetylene flame is, of course, exactly analogous to

FIG. 1.—ACETYLENE FURNACE.

the oxyhydrogen flame, which has long proven useful in laboratories; the only difference is that acetylene gas is substituted for hydrogen. This has two important advantages. The first is that higher temperatures can be produced with the oxyacetylene flame than with the oxyhydrogen flame; the second is due to the very convenient generation of acetylene gas from calcium carbide and water. This is more convenient and safer than the use of compressed hydrogen, and all dangers due to the use of gases, compressed to high pressure in cylinders, are avoided if the oxygen is also generated in a similar way as the acetylene. This is now decidedly practical since the introduction of "oxone" by the Roessler & Hasslacher Chemical Co. (see our Vol. III., p. 255, and the paper of Dr. R. von Foregger, Vol. III., p. 376). The analogy between the generation of oxygen from oxone and water and of acetylene from calcium carbide and water is indeed significant.

However, for most purposes in the laboratory and workshop the highest temperatures which can be obtained with the oxyacetylene flame are not necessary, and in all such cases it means a great simplification, to use not pure oxygen, but atmospheric air. Of course, the air acts here simply as diluted oxygen, so to speak, since the oxygen in the air is the active element and the other constituents are inert. The acetylene is, therefore, used in combination with simple air blast. The heating devices described in the following notes are made by the Harris Calorific Co., of Cleveland.

Fig. 1 shows a small acetylene furnace equipped with a 10-ounce black-lead crucible. The casing holds the heat so perfectly that most refractory substances can be fused with ease, using about two or three pounds pressure air blast from an air compressor or foot blower. By means of the two-in-one valve the supply of gas and air is adjusted in right proportions. A larger type of furnace, with a 2-pound crucible for use of metallurgists, jewelers, chemists and manufacturers of artificial gems, is operated with an air compressor or a very large foot blower.

The blow-pipes made by the Harris Calorific Co. are so designed as to combine in the simplest form every feature required of a perfect blow-pipe. One of their special advantages is to direct the flame inside of a crucible for crucible work. They may be used for heavy brazing in factories, also for heating tools for hardening, for welding light pieces in machine shops, and meet the requirements of glass workers and experimental laboratories. The tubing is never in the way during the operation of the blow-pipe. Fig. 2 shows a hand blow-pipe, with which any desired length of flame may be obtained by adjusting the two-in-one valve in rear of the barrel.

Fig. 3 shows an acetylene Bunsen burner for various laboratory uses and for jewelers, dentists, etc. It is made of the lightest shell brass obtainable, to prevent it from getting hot. The holes are bored accurately to ensure perfect combustion.

Besides the great convenience of these devices, they have the advantage of low cost of apparatus and operation, and the further advantage of safety. Any acetylene generator using a low pressure meets the requirements of the blow-pipes. Portable apparatus is made for places where there is no acetylene available, especially for prospecting work.

* * *

This development is gratifying, since it opens a new and promising field to the acetylene industry, and thereby indirectly to the calcium carbide industry. The time is past when the use of acetylene was thought to involve inherent dangers. This prejudice was due to the early rush of would-be inventors into the acetylene-generator field; most of them undoubtedly possessed mechanical skill, but not the necessary knowledge of the chemistry of the problem of generating acetylene from calcium carbide and water. All this has naturally changed long ago. The less responsible manufacturers have been crowded out; and with the recognized acetylene generators now on the market, accidents are possible only by gross carelessness, just as is the case in electrical engineering or in the use of illuminating gas. An authoritative exposition of the chemistry involved in the generation of acetylene was given in an article by Mr. J. M. Morehead, on page 479 of our Vol. I., to which the reader may be referred.

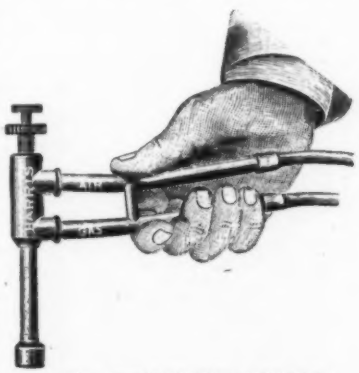


FIG. 2.—ACETYLENE BLOW-PIPE.

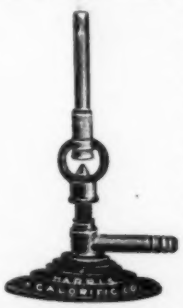


FIG. 3.—ACETYLENE BUNSEN BURNER.

Since, however, many engineers and chemists are still unfamiliar with the working of an acetylene generator, a brief description of a successful modern type should be welcome as the conclusion of these notes. We have chosen Model N, made by the J. B. Colt Co., New York, which, without any reflection on other manufacturers, may undoubtedly be called one of the best developed and most carefully worked-out acetylene generators now available. It is made in capacities varying from 10 to 500 pounds of carbide. Like all reliable types now on the market, it is on the list of permitted machines issued by the National Board of Fire Underwriters. The following description will indicate how exceedingly simple it is to install and to operate:

The Colt generator is shown diagrammatically in Fig. 4. It will be seen that it consists essentially of two parts, the acetylene generator proper at the left hand and the gasometer on the right hand.

The generation of acetylene from calcium carbide takes place according to the equation $CaC_2 + H_2O = CaO + C_2H_2$, and it is evidently possible to design a generator in either of the two following types: The first type comprises those in which a limited amount of water is dropped on to a mass of calcium carbide. This type is known as water-feed generators. The other type comprises those in which limited amounts of carbide are dropped into a large volume of water. They are known as carbide-feed generators. Both types may be so constructed as to operate automatically. In the first case just enough water drops on to the calcium carbide to produce the amount of gas required at that moment. In the second type just enough carbide drops into the water to yield the required amount of gas. But the second type has the inherent advantage that with a large amount of water it is possible to quickly dissipate the heat invariably produced by the chemical reaction. As was pointed out in Mr. Morehead's article above referred to, this is one of the most important requirements of a well designed acetylene generator. For this reason this second principle has been adopted in the Colt acetylene generator.

The automatic carbide-feeding device is at the top. Being

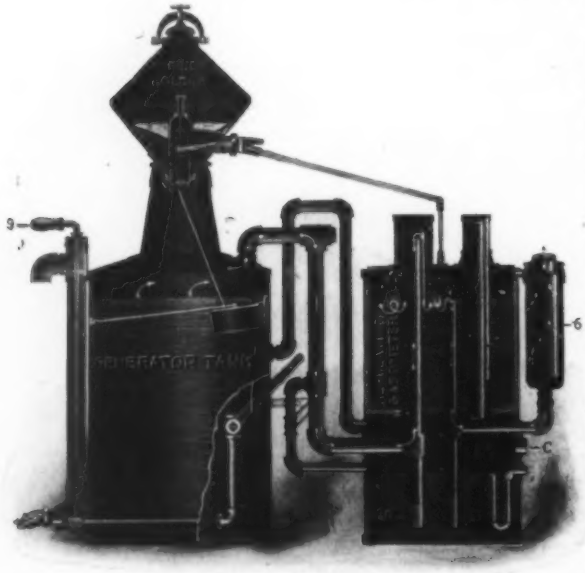


FIG. 4.—ACETYLENE GENERATOR.

located within the carbide holder, it is not affected by the dampness of the water beneath. The feeding of the carbide is so perfectly controlled by the type of valve used that only sufficient is dropped into the water to produce the exact amount of gas that may be required by the burners in operation, whether it be one single burner or the maximum load, so that the gasometer may therefore be made exceedingly compact.

Below the feeding valve is a float cut-off, which serves the important purpose of insuring against a possible operation of the machine when it is not properly filled with water. When the water is at the proper level this cut-off is open; at all other times it is automatically closed. At the bottom of the generator is the water tank, of heavy galvanized sheet steel.

The second main portion of the whole apparatus is the gasometer, which is shown at the right hand of the diagram, and is also constructed of the best grade of galvanized sheet steel. It contains a floating trap, under which the gas is washed and cooled as it passes into the gasometer, and it prevents the gas from escaping when the generator is open for refilling. There is also an improved filter of large area, through which all the gas passes before reaching the service pipe. This filter prevents the passage of lime-dust to the pipes and burners.

The compartment at the bottom of the gasometer serves as the condensation chamber, into which all the condensation in the pipes of the generator is conducted. In this condensation chamber the gas service pipes are water-sealed. This compartment is connected with the open air, so that in case of a slight increase in pressure in the gasometer the excess gas is allowed freely to escape out of doors. It is impossible, therefore, even under conditions due to accident or carelessness, for the pressure to exceed the safety value. On the other hand, as was mentioned above, the automatic carbide-feeding device at the top of the generator works so perfectly that there will be no danger of an undue waste of gas through the exhaust or blow-off pipe from the gasometer.

Air Separation in Grinding Mill.

The adjoining illustrations show the design of the "Cyclone Pulverizer," built according to the patents of Mr. Sydney Straker by Messrs. E. H. Stroud & Co., of Chicago.

In one and the same apparatus a grinding mill, located at the bottom, is combined with a separation chamber, located above, in which the fine particles of the product of the grinding mill are separated from the coarse particles by a method of air-separation. By adjusting the air current the fineness of the product is varied.

The grinding mill works on the principal of attrition grinding, the work effected being due to the high velocity attained by the rotating star or mill wheel. The lumps of raw material, fed to the mill, are reduced by shattering each other to pieces and by the action of the beater arms. This is the same principle as is used in the Cyclone disintegrator of E. H. Stroud & Co., but the distinguishing feature is in the method of air separation.

The mill has no screens, the bottom of the grinding chamber is closed, and above the grinding chamber the air-separation chamber is located, with an exhaust fan on top thereof. The principle of the separation chamber will be easily understood from the illustration. The grist is flung up by the grinding wheel, through the double row of impinging bars in the top of the grinding chamber, into the separating chamber, and this brings it within the range of the exhauster.

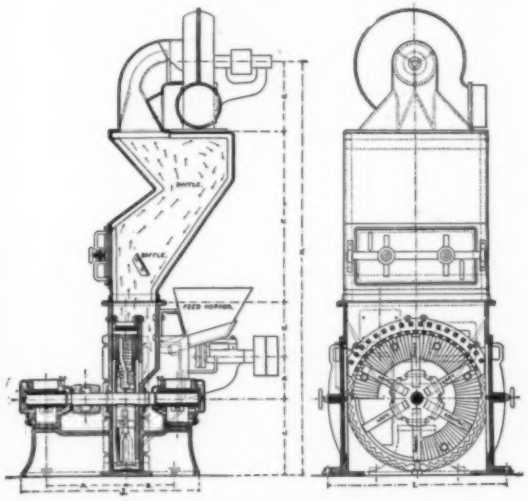
The separation is then effected by specific gravity; *i. e.*, the stronger the current of air induced by the fan the larger are the particles, and the weaker the current of air the smaller are the particles which are delivered from the pulverizer into the settling chamber; and it is only when the material has been reduced to a uniform specific gravity, or to the size of particle which the mill has been "set" to make, that the particles can be and are caught up by the current of air created by the fan and leave the pulverizer.

As the product-laden air rises up through the grinding chamber of the mill into the larger separation chamber it expands, and any heavier particles than the mesh desired fall back automatically by gravity upon and down the incline into the grinding chamber for further reduction. There is no residue. Everything that enters the feed hopper is ground up in one operation. The machine being once "set" to do any specific grade of work it will run day after day without further trouble.

Since a large volume of product-laden air is being delivered every moment from the pulverizer, the high suction-draught induced by the rotating mill wheel and by the fan keeps all passages clear, keeps the mill and its product cool and prevents

objectionable clogging with damp substances. The air will usually absorb and carry off about 10 per cent of moisture, if that much be in the raw material, and with this mill coal and some other materials are readily ground when the moisture runs as high as 15 per cent, so that previous drying of the raw material is frequently unnecessary. There are no sieves to clog.

To change the mesh or fineness of the product of the mill all that is necessary is to open or close a gate at the fan, to reduce or increase the air current, or to move a belt upon a



AIR SEPARATION IN GRINDING MILL.

pair of step-cone pulleys, to alter the speed of the fan to the number of revolutions which will give the required mesh.

The powdered product is discharged into a settling chamber, which may be a simple square room with hopper bottom, built of steel or wood, and with canvass sides to permit the air to escape when the product is delivered.

It will be understood that the mill is specially adapted to reduce dry materials to an impalpable powder, to grind paint pigments, dry colors, drugs and spices. In the Portland cement industry the mill may be used directly in front of each rotary kiln to supply both powdered coal and air to the kiln.

For the treatment of gold and silver ores by the cyanide or by the chlorination process, Messrs. E. H. Stroud & Co. build an extra heavy mill, and are planning also to build this machine in sections small enough for transportation by mules in the mountains. As this pulverizer receives the ore in pieces of large size, say cubes of 2 inches, no other machinery but a crusher is needed. The mill delivers a fine mesh or a coarse one, as desired. If much dust in the product is objectionable, the plant can be adjusted accordingly. If all dust is wanted, this can also be arranged. For use to regrind ores the mill also has many advantages.

Perfect Combustion by Down-Draft.

The problem of producing perfect combustion attracts, just at present, considerable attention. In view of the proverbial London fog, London was recently chosen as the ideal place to hold a conference on smoke abatement, which lasted several days and produced a number of instructive papers. That the matter is an important one in this country also, is indicated by the fact that the New York Section of the Society of Chemical Industry will devote one of its next metings to a general discussion of the same subject.

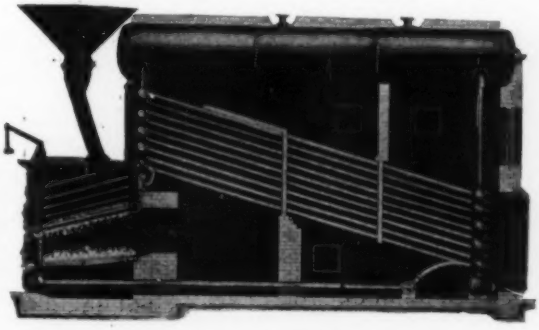
In this connection a brief description of the Hawley down-draft system of the Hawley Down-Draft Furnace Co., of Chicago, should be interesting, since it has already proven its commercial usefulness for quite a number of years in a great many installations.

When coal is fired into a heated furnace, the moisture and volatile matter pass off, leaving each lump of coal an incandescent mass of coke. Much valuable matter passes off with the smoke and is lost, as far as heating value is concerned. Had sufficient air or oxygen been admitted to produce perfect combustion, no smoke would have been made; but sufficient air cannot find its way through the gates and coal to produce perfect combustion before the gases strike the cold surfaces of the boilers, and separated carbon is the result, which cannot be burned, and smoke is produced. Could sufficient air be introduced, and could this air be at a temperature sufficiently high, no smoke would be made.

The Hawley down-draft system is based on the principle to get perfect combustion by mixing hot air with the gases of combustion before they strike the cold boilers and form smoke.

In the Hawley furnace there are two separate grates, one above the other. The upper one is formed of a series of tubes opening at their ends into steel drums, or headers, which in turn are connected with the boiler, through which the boiler water continually and rapidly circulates. It is this upper grate only which is fired, and the down-draft of air being passed from the upper fire doors, the gaseous matter from the green coal consumed on the upper water-tube gates is passed right through this mass of fuel. Whatever gases escape unconsumed are then burned by the flame from the lower grate.

The lower grate, formed of common bars, is entirely fed by the half-consumed fuel falling from the copper grate; and as



DOWN-DRAFT FURNACE.

the flame from this source ascends it meets the downward-burning fire from the upper grate, and the joint draft current passes through the flues in the usual way. The water-tubes and connections give much additional heating surface.

The Hawley down-draft system may be applied to any type of water-tube, tubular or flue boilers. The adjoining illustration shows a Babcock & Wilcox boiler and Hawley down-draft furnace with automatic gravity coal feed.

The manufacturers state that when burning any grade of bituminous coal this system will prevent 95 per cent of the smoke; that it will increase the capacity of the boiler from 25 to 50 per cent, and that it will save from 10 to 40 per cent in cost of fuel. A special advantage is afforded in the fact that the heating surfaces are exposed to practically constant temperatures. There is no alternate heating and cooling, as is the case with the common setting, when the doors are opened to admit fresh charges of fuel.

Gas Reversing Valve.

It is evident from the large number of practical experiments and theoretical suggestions that are made continuously for making a suitable valve, that there are certain distinct diffi-

culties in connection with such devices. What is desired is an absolutely tight valve which will keep tight. The valves up to the present time either work with faced surface or with water seal. Both of these ways have certain disadvantages. At the high heat the iron warps after a short time and is then rapidly destroyed. In the case of the water seal, the hot gases come in contact with water and are considerably cooled off, a part of the water being carried in form of vapor by the gases to the furnace, thereby deteriorating the gas.

An important advance in this field has been made by Mr. Fischer, a well-known German engineer. This valve, which does away with the above difficulties, can be put in without changing the brick work and the present gas connection; it is of simple construction, as can be seen from the illustrations and from this description.

The Fischer valve consists of three main parts, an inner cylinder with a wall across and an outer cylinder, which is made in four compartments with four ribs, and then the base plate.

The inner cylinder *A* is pressed by the outside weight, shown in one of the diagrams, to the lower face *C* of the upper ring,

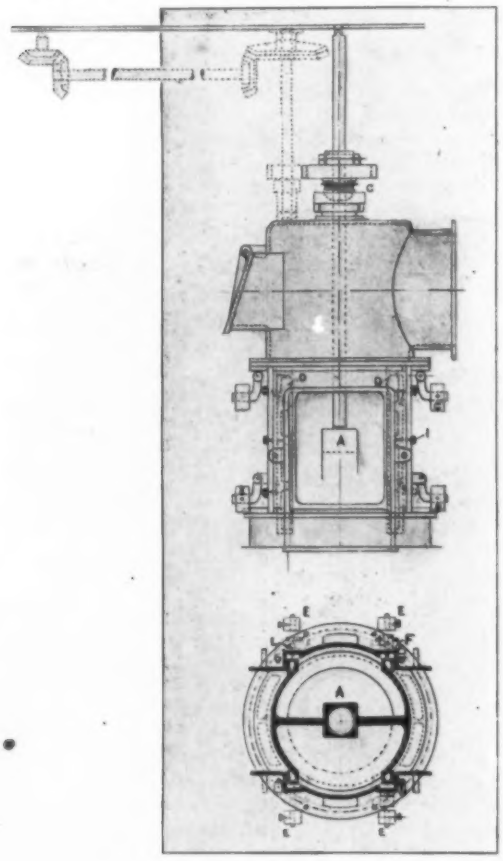


DIAGRAM OF GAS VALVE.

whereby the upper joint is kept tight. The space of play between the inner cylinder and outer cylinder can be made as desired, and the connection between the two cylinders is made by four ribs, which are effecting a tight joint on the sides. These four ribs are pressed by the weight *E* against the inner cylinder. The ribs *D* can be lifted by loosening the bolt *I*, whereby a connection is made from producer to stack for burning out the pipes, etc. The lower joint is made tight by having the inner cylinder resting in sand on the base plate. The pieces *L* prevent a throwing out of the center. The inner cylinder rests in the ball-bearing *O*, which allows an easy handling, and rests on the button, whereby an absolute horizontal position of the inner cylinder is effected.

It can be seen from this description that the Fischer valve is absolutely tight and does not allow an escape of the gas in any direction. Another important advantage is the point that during changing the position of the valve the connection between stack and producer is absolutely shut, and that the gas contained in the chambers and pipes is going to the furnace.

With the present valves even at a short shut-down the chambers and furnace cool off considerably as the slide valve in the stack is never absolutely tight.

The Fischer valve, on the other hand, is absolutely closed by a half-turn. By the use of this valve every leakage is prevented and also the loss and deterioration of the gas when changing the position of the valve. This results in a saving of fuel up to 30 per cent with the Fischer valve, so that it is to the interest of every steel furnace management to use this valve, which, besides the mentioned advantages, has a very long life and is subjected to very much less repairs than the present system.

The advantages of this valve are simple construction, a large saving in fuel, long life, small repairs.

This valve has now been on the market in Germany for about three years, and in that short time it has been introduced into practically every important steel plant in Germany, Austria and Italy. Some of the largest steel plants have entirely removed their old valves and have replaced all of them to the very best of satisfaction with this valve.

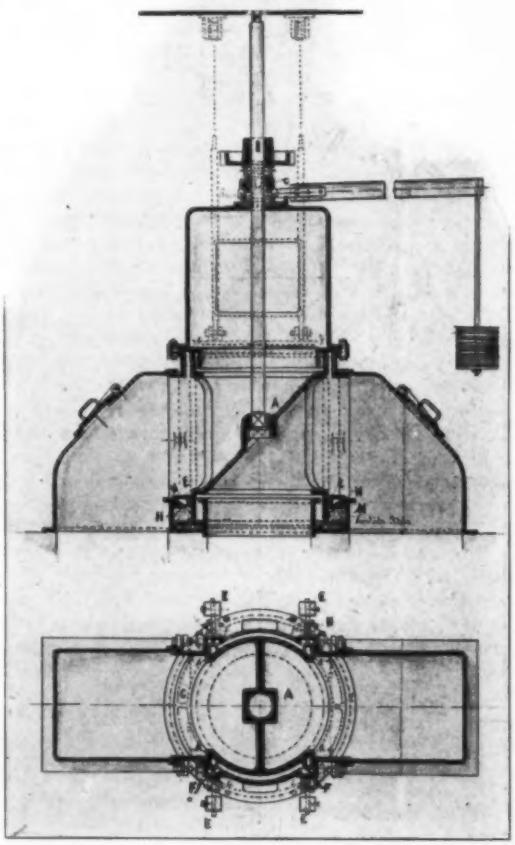


DIAGRAM OF GAS VALVE.

These valves are built in this country by Dr. Oskar Nagel, engineer, 90 Wall Street, New York City, who holds the American rights.

Industrial Notes.

Niagara Falls.—The first permanent aluminium cable which supplies the Niagara, Lockport & Ontario Power Co. with power from the Ontario Power Co. was stretched across the Niagara gorge just below the whirlpool in January. The transmission line will extend from this point to Syracuse, and power is contracted for in Syracuse for March delivery. A contract has been made by this company for 25,000 horse-power to be used in the electrification of New York Central branch lines. The trunk lines, it is understood, will be electrified soon after. At the point where the transmission line strikes the American side, the Ontario Power interests have bought 1,200 acres of land just outside the city limits of Niagara Falls. A big industrial development is looked for here, as every inducement in the nature of cheap power and land and excellent transportation facilities is offered a prospective manufacturer. The Ontario Power Co. is developing 250,000 e. h. p., machinery for 50,000 e. h. p. being already installed. Most of this power will be available for American use. It is said that the Ontario Power Co. is about to close with several electrochemical concerns.

Calendars.—We have received a number of artistic calendars for 1906. The ferro-alloy calendar of Roessler & Hasslacher Chemical Co. has a picture of Patzcuaro Lake, Mexico. Messrs. E. A. Dempwolf & Sons, makers of hydrofluoric acid, York, Pa., have as picture the wedding breakfast of an Indian girl. The calendar of the National Carbon Co. shows a rather pretty girl with a muff. The calendar of the Charles E. Sholes Co. and J. T. Baker Co. has the official list of atomic weights for 1906. The Westinghouse Co. has again issued their extremely neat and useful diary, bound in black leather, and containing besides a number of maps, a large amount of concise information and useful data for electrical engineers.

Metallurgical Machinery.—Among the well-written and neatly, as well as profusely, illustrated new publications recently issued by the extremely active department of publicity of the Allis-Chalmers Co., of Milwaukee, Wis., are the following: Bulletin 1,408 gives a very full description of the Tremain steam stamp, which has been designed especially to meet the demands of those who own mining properties in the first stages of development, and enables them to establish a thoroughly good crushing, amalgamating, or concentrating plant of moderate capacity, in the shortest possible time, with the least material and for the least money. Bulletin 1,704 deals with lath mills and bolters, Bulletin 1,202 with the Reliance friction clutch, which has been designed for the heaviest work. It is of the disc type, in which a cast-iron disc is clamped between two continuous wood surfaces. The clutch is made with either three or six arms, arranged in sets of three. Each of the sets is connected to an equalizing ring by toggles, and this ring is free to move sideways, so as to equalize the strain on the three arms. The power is thus distributed uniformly over the entire friction surfaces, and the clutch does not have to carry any one-sided strains. There are no springs used in this mechanism, the pressure on the friction surfaces being set according to the load the clutch has to carry by means of adjusting nuts on the eye-bolts. The space between these nuts is filled by a ferrule, so that the nuts do not bind on the clamp ring, and, when set up, they form a positive lock. The sleeve carries the operating mechanism, and when the clutch is not in operation is the only wearing part.

Aluminium.—The Pittsburgh Reduction Co. has acquired a parcel of land in the neighborhood of Main and James Streets, Niagara Falls, as a site for a mill for the rolling of aluminium plates and wires. The company now has a rolling mill in New Kensington, Pa., but the market for aluminium plates and wire has increased so rapidly lately that the Kensington mill has not been able to supply the demand. The mill at Niagara will cover 4 acres of ground, and the dimensions of the main building will be 200 x 100 feet.

Pyrometers.—The reunion of the American Society of Mechanical Engineers, held on Jan. 30, had for its central feature a discussion by Prof. W. H. Bristol, of Stevens Institute, on thermoelectric pyrometers, adapted for general industrial purposes. The address was illustrated with demonstrations of the speaker's new type of thermoelectric pyrometer, which was already exhibited by Mr. F. F. Schuetz at the Bethlehem meeting of the American Electrochemical Society. We hope to give a more detailed description in one of our next issues.

Electric Equipment of Iron Mine.—A report from Duluth, Minn., states that the Penn Iron Mining Co. has made a contract for the erection of a hydro-electric plant and the equipment of its entire mines with electrically-driven machinery. The water power of the Sturgeon Falls, a few miles from the mines, will be developed, and a total of 4,000 hp. will be used. The General Electric Co. has the contract. This is believed to be the most complete electrical equipment that has ever been put into an iron mine. The Penn production is about 450,000 tons a year, and is gradually increasing. The cost of fuel consumed during the past year is estimated as more than $100,000, which item will, of course, be eliminated in future by the generation of electrical energy from water power.

Storage Battery Manufacture.—We are authentically informed that on account of the great increase in the demand for its "Bijur High-Duty" cells, the General Storage Battery Co. has decided to enlarge its factory at Boonton, N. J., by erecting buildings furnishing an additional 48,000 square feet of floor space; they will install hydraulic and steam or gas generating machinery aggregating over 1,000 horse-power.

Oil as Fuel.—A recent fully illustrated catalogue of the De La Vergne Machine Co. deals with "Hornsby-Akroyd" oil engines. There are now over 10,000 of these engines in operation. They use as fuel ordinary kerosene, crude oil or fuel oil. Their ability to operate successfully under varying loads with these oils, which can be bought for from 1 to 5 cents per gallon, make them valuable where such oils can be cheaply procured. A test of a 25-horse-power Hornsby-Akroyd oil engine showed the following consumption of oil in pounds:

	Per Indicated Hp-hour.	*Per Brake Hp-hour.*
Full load	0.62	0.74
Two-thirds	0.74	0.91
One-third	0.91	1.3
No load	1.3	...

The actual cost of power for a 125-horse-power single-cylinder engine for 1 hp-year, equal to 3,000 hp-hours, is stated to be $25.37 (including crude oil at 3 cents per gallon, lubricating oil, attendance and interest on investment, depreciation at 12 per cent). Of the total cost of $25.37 the single item of the cost of oil is $9.27, at the rate of 3 cents per gallon. In many localities oil can be procured at 1.5 cents or less per gallon. In this case the cost of power will be correspondingly less.

Coating for Iron Structures, Tanks, Pipes.—Several years ago the Solvay Process Co., of Syracuse, N. Y., found it necessary to procure a coating for the protection of their buildings, machinery, tank cars, submerged and structural iron work and piping, which extends for miles about their plants. The task was not an easy one, but was well worth trying, in view of the endless destruction and expense caused by the chemical fumes, gases, etc., in the atmosphere. The problem which the chemists of the Solvay Co. had to solve was the preparation of an elastic, impervious substance that would be rust, water, sun, weather, acid and fire-proof. The outcome of these experiments is a material which has now been placed on the market, under the trade name "Crysolite," Messrs. Fuerst Bros. & Co., of New York City, being the distributing agents. The analysis of crysolite proves it to be the purest possible form of carbon combined with a special oil as carrier, so that it forms a smooth, impervious, elastic, durable coating. Before being

placed on the market, crysolite was subjected to very severe tests, which it stood very satisfactorily. Thus Mr. J. D. Pennock, the well-known chief chemist of the Solvay Co., reports that wrought-iron tubes, 3 inches in diameter, were painted and exposed, after a baking process, to the action of ammonia and ammonium chloride liquors for three months, and when the pipes were removed they were found in perfect condition. In another test sheet-iron plates, 6 x 3, were painted with crysolite and exposed for two months in sea water, at the end of the two months the sheets showed no tendency whatever to rust, and the coating was in a hard, tough, yet elastic condition. The corrosion of iron has been a large factor in the past in increasing the cost of maintenance of plants in the chemical, metallurgical and mining industries, and there should be, therefore, an immense field of usefulness for a coating with the described properties in these fields.

Cyanide Process Developments in South Dakota.—It is reported from Deadwood, S. D., that the Clover Leaf Mining Co. is installing a powerful pumping plant to keep the water in the Uncle Sam mine, located south of Deadwood, under control. The company has a sixty-stamp mill at the mine, and has an abundance of ore of an average grade of $6 a ton. The mine has some rich streaks. In the early days it made several fortunes for the owners, who stamped out the gold in a crude way. Mr. Pierre Wiebaux, of Miles City, Mont., is president of the company. Mr. J. V. N. Dorr, of Terry, is drawing the plans for the remodeling of the Kildonan mill at Pluma for the Horseshoe Co. The Lundburg-Dorr-Wilson mill at Terry is among the most complete and profitable cyanide mills in the Black Hills. It saves the values in the slimes by the use of the Moore slime process. It is possible that the same methods used in the Terry mill will be put into use at the Horseshoe plant at Pluma. A description of the Moore slimes process and of the working of the Terry mill was given on page 257 of our Vol. III. Reports from Hill City state that the famous Clara Bell mine southeast of this place is rapidly becoming a big mine. A shaft that was put down a few weeks ago 300 feet encountered a vein where the ore averaged $16 a ton. Another shaft is being sunk further along in the dip. Several Ohio capitalists have bought the control of this mine from Herbert Bros., and a large mill is to be built.

Electric Hoist.—Electric Hoisting Machinery is the title of the latest illustrated bulletin issued by the Crocker-Wheeler Co. Electric hoists are now employed in all places and under all conditions where steam power was formerly used, and in many instances, such as in mines and tunnels, electric apparatus are the only type which has proven successful. As compared with steam or pneumatic hoists the motor-driven machines have the great advantage of being able to dispense with the boiler or compressor, which renders them much easier to transport and at the same time does away with the service of the firemen.

Personal.

Mr. Woolsey McA. Johnson has returned from a commercial trip to Mexico.

Mr. B. C. Hesse has opened offices as chemical expert at 90 William Street, New York City, making a specialty of organic chemistry.

Mr. Edgar A. Ashcroft, the distinguished British electrometallurgist, is at present in this country and recently visited several electrochemical plants at Niagara Falls.

Messrs. C. C. Speiden and Marion Speiden, having for many years past been associated with Messrs A. Klipstein & Co., have recently severed this connection to become directors of the firm of Innis, Speiden & Co., successors to the old firm of Innis & Co.

Digest of U. S. Patents.

Compiled by Byrnes & Townsend, Patent Lawyers, National Union Building, Washington, D. C.

Production of Nitrogen Compounds.

No. 569,122, Oct. 6, 1896, A. A. Naville and P. A. and C. E. Guye, Geneva, Switzerland.

The apparatus is a eudiometer designed to operate continuously and to expose every portion of the gases to the action of the electric spark. It comprises a vessel having opposed tubular spark terminals, between which are a number of intermediate tubular electrodes, all of these tubes being connected to a single discharge pipe, and the arrangement being such that the entering gases flow simultaneously into and through several tubes connected electrically in series and serving as discharge surfaces. The terminals and intermediate tubes may be of carbon or of metal, as of platinum, bronze, copper, nickel, ferronickel, etc., the selection of the electrode material depending on the character of the gas reaction sought. Examples given are the production of nitric acid from moist air in the presence of carbon electrodes, and the production of acetylene from hydrogen in presence of carbon electrodes.

No. 569,325, Oct. 13, 1896. Paul Danckwardt, New York, N. Y.

Fused alkali chloride, as NaCl or KCl, or a mixture of these with calcium chloride, is electrolyzed between a carbon anode and a sheet-metal cathode, the latter constituted by the walls of the containing vessel, the top and bottom of the vessel being suitably insulated. The anode is surrounded by a perforated clay tube, which serves to lead the chlorine from the apparatus. The liberated alkali metal rises to the surface, and is there brought into contact with carbon and nitrogen, for the purpose of producing the corresponding cyanide. The carbon may be present as a body of coal floating upon the fused salt, or as a gaseous compound as carbon monoxide. The nitrogen may be introduced as free nitrogen, as a nitrogen compound, as uric acid, or preferably in the form of ammonia gas. The reaction between carbon, sodium and ammonia proceeds with separation of hydrogen, in accordance with the equation

$$C + Na + NH_3 = NaCN + H_2$$

No. 579,988, April 6, 1897, Carl Kellner, Vienna, Austria-Hungary.

Cyanides are produced by direct reduction of nitrates or nitrites by means of an electric arc between carbon electrodes, the reaction proceeding according to the equations

$$(1)\ KNO_3 + 4C = KCN + 3CO$$
$$(2)\ KNO_2 + 3C = KCN + 2CO$$

In order to facilitate the reaction the nitrate or nitrite may be mixed with carbon. The apparatus may comprise vertical or horizontally-disposed carbon electrodes, with any suitable means for feeding the charge to the zone of reduction.

No. 607,943, July 26, 1898, H. Mehner, Berlin, Germany.

Cyanides are produced in an electric furnace by reaction between alkali or alkali earth compounds, carbon and nitrogen, the preferred material being the alkali or alkali earth carbonates. Owing to the high temperature the resulting cyanide is vaporized; the vapors are withdrawn from the furnace at a point immediately below the zone of highest heat, and are condensed in a column of coke, contained in a shaft above the electric furnace. This coke, containing the condensed cyanide, is steamed at suitable temperature, whereby the cyanides are converted into ammonia, leaving a residue consisting of the coke and the corresponding carbonate. This forms a suitable charge for the electric furnace, and is admitted directly thereto for the continuance of the reaction. The construction is such that the condensation occurs only in the remoter layers of the coke column, and arrangements are made for preliminarily heating the air which serves as a source of nitrogen supply for the reaction furnace